

# Detailed Member Calculations

**Units: N&mm**

**Regulation: ASCE 41-17**

## Calculation No. 1

column C1, Floor 1

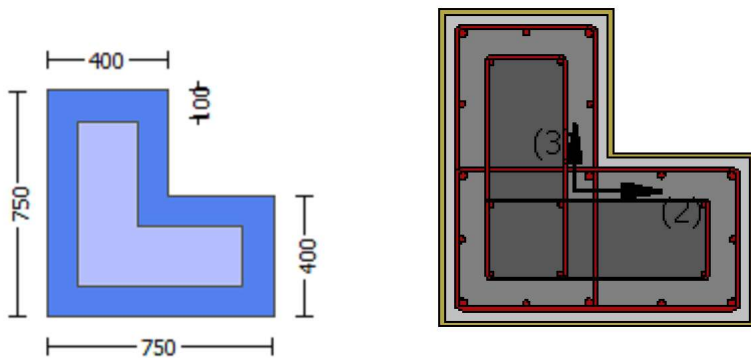
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjls

Constant Properties

Knowledge Factor,  $\gamma = 0.90$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
#####  
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,  
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as  
Deformation-Controlled Action (Table C7-1, ASCE 41-17).  
Jacket  
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
Existing Column  
Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = l_b = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

EDGE -A-  
Bending Moment,  $M_a = -1.5690E+007$   
Shear Force,  $V_a = -5209.785$   
EDGE -B-  
Bending Moment,  $M_b = 56787.791$   
Shear Force,  $V_b = 5209.785$   
BOTH EDGES  
Axial Force,  $F = -16800.923$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 5353.274$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{l,ten} = 1137.257$   
-Compression:  $As_{l,com} = 2208.54$   
-Middle:  $As_{l,mid} = 2007.478$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $VR = *V_n = 558275.125$

$V_n ((10.3), ASCE 41-17) = k_n I^* V_{ColO} = 620305.695$

$V_{Col} = 620305.695$

$k_n I = 1.00$

$displacement\_ductility\_demand = 0.02232182$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_c\_jacket \cdot Area\_jacket + f'_c\_core \cdot Area\_core) / Area\_section = 21.31818$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 4.00$

$\mu_u = 1.5690E+007$

$V_u = 5209.785$

$d = 0.8 \cdot h = 600.00$

$N_u = 16800.923$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 126213.67$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 55439.87$

$V_{sj1} = 0.00$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 510.00$

$V_{sj1}$  is multiplied by  $Col,j1 = 0.00$

$s/d = 1.59375$

$V_{sj2} = 55439.87$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 510.00$

$V_{sj2}$  is multiplied by  $Col,j2 = 0.60$

$s/d = 0.85$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 70773.799$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 70773.799$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), ACI 440) = 372533.843$

$f = 0.95$ , for fully-wrapped sections

$w_f / s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,

where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 736127.561$

$b_w = 400.00$

displacement\_ductility\_demand is calculated as  $\delta / y$

- Calculation of  $\delta / y$  for END A -  
for rotation axis 3 and integ. section (a)

From analysis, chord rotation  $\theta = 6.3679592E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.0028528$  ((4.29), Biskinis Phd))

$M_y = 4.1179E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3011.65

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 16800.923$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 3.0742160E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 350.6021$

$d = 707.00$

$y = 0.19345095$

$A = 0.01018613$

$B = 0.00449653$

with  $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 16800.923$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6463045E-005$

with  $f_c' (12.3, (ACI 440)) = 33.48734$

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e / A_c = 0.31291181$

Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$

effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19180888$

$A = 0.01002479$

$B = 0.00440616$

with  $E_s = 200000.00$

CONFIRMATION:  $y = 0.19276987 < t/d$

Calculation of ratio  $I_b / I_d$

Lap Length:  $l_d/l_{d,min} = 0.38498739$

$l_b = 300.00$

$l_d = 779.2463$

Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 510.00$

$n = 24.00$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 2

column C1, Floor 1

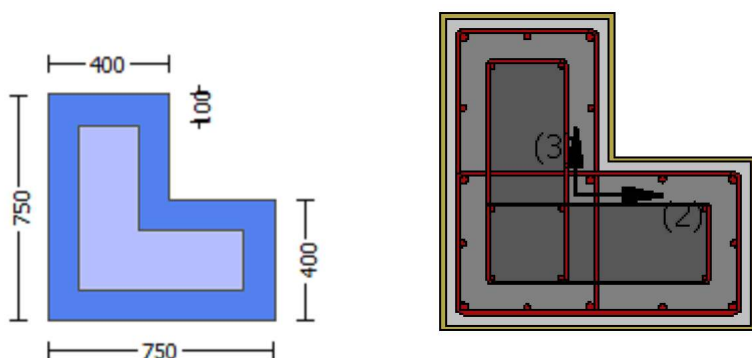
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\mu$ )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlc

## Constant Properties

Knowledge Factor,  $\phi = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.03889

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -0.00051441$

EDGE -B-

Shear Force,  $V_b = 0.00051441$

BOTH EDGES

Axial Force,  $F = -16273.616$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1137.257$

-Compression:  $As_{l,com} = 2208.54$

-Middle:  $As_{l,mid} = 2007.478$

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.81868759$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$   
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.0265E+008$

$M_{u1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.0265E+008$

$M_{u2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $M_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 8.9479397E-006$

$M_u = 4.8921E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

$\phi_{co} (5A.5, \text{TBDY}) = 0.002$

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01186911$

we ((5.4c), TBDY) =  $a_{se} * \phi_{u, \min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{ux}, \phi_{uy}) = 0.04377629$

where  $\phi = a_f * \phi_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{ux} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$\phi_{uy} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} ((5.4d), \text{TBDY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.11512199$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 510.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0014252$$

$$sh1 = 0.00456062$$

$$ft1 = 449.345$$

$$fy1 = 374.4542$$

$$su1 = 0.00542681$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30798991$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 374.4542$$



with  $E_{s1} = (E_{sjacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 200000.00$   
 $y_2 = 0.0014252$   
 $sh_2 = 0.00456062$   
 $ft_2 = 455.1997$   
 $fy_2 = 379.3331$   
 $su_2 = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} \cdot A_{s,com,jacket} + fs_{core} \cdot A_{s,com,core}) / A_{s,com} = 379.3331$   
 with  $E_{s2} = (E_{sjacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} \cdot A_{s,mid,jacket} + fs_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 377.6747$   
 with  $E_{sv} = (E_{sjacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / f_c) = 0.02433675$   
 $2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / f_c) = 0.04787748$   
 $v = A_{s,mid} / (b \cdot d) \cdot (fs_v / f_c) = 0.04332854$   
 and confined core properties:  
 $b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / f_c) = 0.0276252$   
 $2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / f_c) = 0.05434683$   
 $v = A_{s,mid} / (b \cdot d) \cdot (fs_v / f_c) = 0.04918322$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.14216778$   
 $\mu_u = M_{Rc} (4.14) = 4.8921E+008$   
 $u = su (4.1) = 8.9479397E-006$

#### Calculation of ratio $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$   
 $l_b = 300.00$   
 $l_d = 974.0579$   
 Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} < =$

8.3 MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$

$n = 24.00$

Calculation of  $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.7291088\text{E}-006$

$\mu_1 = 8.0265\text{E}+008$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00174378$

$N = 16273.616$

$f_c = 33.00$

$\alpha_1(5A.5, \text{TBDY}) = 0.002$

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha_1) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu = 0.01186911$

$\mu_e(5.4c, \text{TBDY}) = \alpha_1 * \text{sh}_{\text{min}} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$

where  $f = \alpha_1 * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$\alpha_{se}((5.4d), \text{TBDY}) = (\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}})/A_{\text{sec}} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
Aconf,min1 = 71100.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 0.87336895$

Expression (5.4d) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 455.1997

fy1 = 379.3331

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min =  $l_b/l_d = 0.30798991$

su1 =  $0.4 * e_{s1\_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 379.3331$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.0014252

sh2 = 0.00456062

ft2 = 449.345

fy2 = 374.4542

su2 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 374.4542$   
with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 377.6747$   
with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.08977028$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.0456314$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.08124101$   
and confined core properties:  
 $b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.11029209$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05606291$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.099813$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)  
--->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.2110448$   
 $Mu = MRc (4.14) = 8.0265E+008$   
 $u = su (4.1) = 9.7291088E-006$

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Calculation of ratio  $l_b/l_d$

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Lap Length:  $l_b/l_d = 0.30798991$   
 $l_b = 300.00$   
 $l_d = 974.0579$   
Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $fy = 655.558$   
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} < =$   
8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$$s = \max(s_{external}, s_{internal}) = 510.00$$

$$n = 24.00$$

Calculation of  $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.9479397E-006$$

$$\mu_{2+} = 4.8921E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_{2+}: \mu_{2+}^* = \text{shear\_factor} * \max(\mu_{2+}, \mu_{2+}^c) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{2+}^c = 0.01186911$$

$$\mu_{2+}^c \text{ ((5.4c), TBDY) } = \alpha_{se} * \mu_{2+}^c * \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.04377629$$

where  $f_x = \alpha_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY) } = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$\alpha_{se1} = \max((A_{conf,max1} - A_{noConf1}) / A_{conf,max1} * (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 510.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0014252$$

$$sh1 = 0.00456062$$

$$ft1 = 449.345$$

$$fy1 = 374.4542$$

$$su1 = 0.00542681$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30798991$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{nominal} = 0.08,$$

For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 374.4542$$

$$\text{with } Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$$

$$y2 = 0.0014252$$

$$sh2 = 0.00456062$$

$$ft2 = 455.1997$$

$$fy2 = 379.3331$$

$$su2 = 0.00542681$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$$

$$su2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_{nominal} = 0.08,$$

For calculation of  $es_{u2\_nominal}$  and  $y_2$ ,  $sh_{2ft2}$ ,  $fy_2$ , it is considered characteristic value  $fs_{y2} = fs_2/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_{1ft1}$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 379.3331$

with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

$y_v = 0.0014252$

$sh_v = 0.00456062$

$ft_v = 453.2097$

$fy_v = 377.6747$

$suv = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.30798991$

$suv = 0.4 \cdot es_{u\_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $es_{u\_nominal} = 0.08$ ,

considering characteristic value  $fs_v = fs_v/1.2$ , from table 5.1, TBDY

For calculation of  $es_{u\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered characteristic value  $fs_v = fs_v/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_{1ft1}$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 377.6747$

with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

$1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.02433675$

$2 = Asl_{com}/(b \cdot d) \cdot (fs_2/f_c) = 0.04787748$

$v = Asl_{mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.04332854$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.0276252$

$2 = Asl_{com}/(b \cdot d) \cdot (fs_2/f_c) = 0.05434683$

$v = Asl_{mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.04918322$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.14216778$

$Mu = MRc (4.14) = 4.8921E+008$

$u = su (4.1) = 8.9479397E-006$

-----

Calculation of ratio  $lb/ld$

-----

Lap Length:  $lb/ld = 0.30798991$

$lb = 300.00$

$ld = 974.0579$

Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 510.00$

$n = 24.00$

-----

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## Calculation of Mu2-

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.7291088E-006$$

$$\mu_u = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$\nu = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha_1(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \mu_u = 0.01186911$$

$$\mu_{cc} \text{ ((5.4c), TB DY)} = \alpha_1 * \rho_{frp} * f_{fe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.04377629$$

where  $\mu_{fx} = \alpha_1 * \rho_{frp} * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{fx} = 0.04286225$$

Expression ((15B.6), TB DY) is modified as  $\alpha_1 = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_1 = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A4.4.3(6), } \rho_{frp} = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\mu_{fy} = 0.04286225$$

Expression ((15B.6), TB DY) is modified as  $\alpha_1 = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_1 = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A4.4.3(6), } \rho_{frp} = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TB DY)} = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (>= \alpha_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.12134906$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.



Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 455.1997$

$fy1 = 379.3331$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.30798991$

$su1 = 0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket} \cdot A_{sl,ten,jacket} + fs_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 379.3331$

with  $Es1 = (Es_{jacket} \cdot A_{sl,ten,jacket} + Es_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 449.345$

$fy2 = 374.4542$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{u,min} = lb/lb_{min} = 0.30798991$

$su2 = 0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y2$ ,  $sh2$ ,  $ft2$ ,  $fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs_{jacket} \cdot A_{sl,com,jacket} + fs_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 374.4542$

with  $Es2 = (Es_{jacket} \cdot A_{sl,com,jacket} + Es_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$

$yv = 0.0014252$

```

shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
lo/lo,min = lb/ld = 0.30798991
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^2/3), from 10.3.5, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.08977028
2 = Asl,com/(b*d)*(fs2/fc) = 0.0456314
v = Asl,mid/(b*d)*(fsv/fc) = 0.08124101
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
    c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11029209
2 = Asl,com/(b*d)*(fs2/fc) = 0.05606291
v = Asl,mid/(b*d)*(fsv/fc) = 0.099813
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.2110448
Mu = MRc (4.14) = 8.0265E+008
u = su (4.1) = 9.7291088E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.30798991
lb = 300.00
ld = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 0.8418647
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 510.00
n = 24.00
-----
-----
-----
-----
Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 653603.866
-----
Calculation of Shear Strength at edge 1, Vr1 = 653603.866
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0

```

VColO = 653603.866

knl = 1 (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77537$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 140237.117$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 61600.349$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.60$

$s/d = 0.85$

$V_{s,j2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.00$

$s/d = 1.59375$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 78636.768$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 0.00$

$s/d = 1.5625$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $\alpha$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\alpha)$ , is implemented for every different fiber orientation  $\alpha_i$ , as well as for 2 crack directions,  $\alpha = 45^\circ$  and  $\alpha = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\alpha_1 = \alpha_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$

$b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$

$Vr2 = VCol \text{ ((10.3), ASCE 41-17)} = knl * VCol0$

$VCol0 = 653603.866$

$knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $Vs = Av * fy * d / s$ ' is replaced by ' $Vs + f * Vf$ '  
where  $Vf$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 4.00$

$Mu = 11.77482$

$Vu = 0.00051441$

$d = 0.8 * h = 600.00$

$Nu = 16273.616$

$Ag = 300000.00$

From (11.5.4.8), ACI 318-14:  $Vs = Vs_{jacket} + Vs_{core} = 140237.117$

where:

$Vs_{jacket} = Vs_{j1} + Vs_{j2} = 61600.349$

$Vs_{j1} = 61600.349$  is calculated for section web jacket, with:

$d = 600.00$

$Av = 157079.633$

$fy = 555.56$

$s = 510.00$

$Vs_{j1}$  is multiplied by  $Col_{j1} = 0.60$

$s/d = 0.85$

$Vs_{j2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$Av = 157079.633$

$fy = 555.56$

$s = 510.00$

$Vs_{j2}$  is multiplied by  $Col_{j2} = 0.00$

$s/d = 1.59375$

$Vs_{core} = Vs_{c1} + Vs_{c2} = 78636.768$

$Vs_{c1} = 78636.768$  is calculated for section web core, with:

$d = 440.00$

$Av = 100530.965$

$fy = 444.44$

$s = 250.00$

$Vs_{c1}$  is multiplied by  $Col_{c1} = 1.00$

$s/d = 0.56818182$

$Vs_{c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$Av = 100530.965$

$fy = 444.44$

$s = 250.00$

$Vs_{c2}$  is multiplied by  $Col_{c2} = 0.00$

$s/d = 1.5625$

$Vf \text{ ((11-3)-(11.4), ACI 440)} = 372533.843$

$f = 0.95$ , for fully-wrapped sections

$wf/sf = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
where  $\theta$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $Vf(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, \theta_1)|, |Vf(-45, a_1)|)$ , with:

total thickness per orientation,  $tf_1 = NL * t / NoDir = 1.016$

$dfv = d$  (figure 11.2, ACI 440) = 707.00

$ffe \text{ ((11-5), ACI 440)} = 259.312$

$Ef = 64828.00$

$fe = 0.004$ , from (11.6a), ACI 440

with  $fu = 0.01$

From (11-11), ACI 440:  $Vs + Vf \leq 838832.606$

$bw = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjlc3

#### Constant Properties

Knowledge Factor,  $\gamma = 0.90$   
Mean strength values are used for both shear and moment calculations.  
Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,  
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.03889

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $N_{oDir} = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -0.00051441$

EDGE -B-

Shear Force,  $V_b = 0.00051441$   
 BOTH EDGES  
 Axial Force,  $F = -16273.616$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $As_t = 0.00$   
   -Compression:  $As_c = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $As_{t,ten} = 1137.257$   
   -Compression:  $As_{c,com} = 2208.54$   
   -Middle:  $As_{mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.81868759$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$   
 with  
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 8.0265E+008$   
 $\mu_{u1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $\mu_{u1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 8.0265E+008$   
 $\mu_{u2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination  
 $\mu_{u2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $\mu_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 8.9479397E-006$   
 $\mu_u = 4.8921E+008$

with full section properties:

$b = 750.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093001$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\phi_c (5A.5, \text{TB DY}) = 0.002$

Final value of  $\phi_{cu}$ :  $\phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY:  $\phi_{cu} = 0.01186911$

we ((5.4c), TB DY) =  $a s_e * \phi_{sh,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.04377629$

where  $\phi_f = a f * \phi_{pf} * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $a f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a f = 0.31984848$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_{pf} = 2 t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$\phi_{fy} = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $a f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a f = 0.31984848$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$b_{max} = 750.00$

hmax = 750.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$   
bw = 400.00  
effective stress from (A.35),  $ff,e = 870.5244$

R = 40.00  
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_f = 0.015$

$ase((5.4d), TBDY) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.11512199$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.11081094$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh,min*F_{ywe} = \text{Min}(psh,x*F_{ywe}, psh,y*F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh,min*F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.000721$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2(5.4d) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

$psh,y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.000721$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2((5.4d), TBDY) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

c = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 449.345$

$fy1 = 374.4542$

```

su1 = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.30798991
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 374.4542
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0014252
sh2 = 0.00456062
ft2 = 455.1997
fy2 = 379.3331
su2 = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.30798991
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 379.3331
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0014252
shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.30798991
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006

```



#### Calculation of ratio $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$

$l_b = 300.00$

$l_d = 974.0579$

Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$

$n = 24.00$

#### Calculation of $\mu_{u1}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$\mu_u = 9.7291088\text{E-}006$

$\mu_u = 8.0265\text{E+}008$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00174378$

$N = 16273.616$

$f_c = 33.00$

$\alpha_c$  (5A.5, TBDY) = 0.002

Final value of  $\alpha_c$ :  $\alpha_c^* = \text{shear\_factor} \cdot \text{Max}(\alpha_c, \alpha_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\alpha_c = 0.01186911$

we ((5.4c), TBDY) =  $\alpha_c \cdot \text{sh}_{\text{min}} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$

where  $f = \alpha_c \cdot p_f \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_f = 0.015$   
 $ase \ ((5.4d), TBDY) = (ase_1 \cdot A_{ext} + ase_2 \cdot A_{int}) / A_{sec} = 0.11512199$   
 $ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$   
The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase_2 \ (\geq ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$   
The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 0.87336895$   
Expression (5.4d) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 0.87336895$   
 $p_{sh1} \ ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2} \ ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548  
-----

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 0.87336895$   
 $p_{sh1} \ ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2} \ ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548  
-----

$A_{sec} = 440000.00$   
 $s_1 = 510.00$   
 $s_2 = 250.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$   
 $c$  = confinement factor = 1.03889

$y_1 = 0.0014252$   
 $sh_1 = 0.00456062$   
 $ft_1 = 455.1997$   
 $fy_1 = 379.3331$   
 $su_1 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 0.30798991$   
 $su_1 = 0.4 \cdot esu_1_{nominal} \ ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = (fs\_jacket \cdot Asl\_ten\_jacket + fs\_core \cdot Asl\_ten\_core) / Asl\_ten = 379.3331$   
with  $Es1 = (Es\_jacket \cdot Asl\_ten\_jacket + Es\_core \cdot Asl\_ten\_core) / Asl\_ten = 200000.00$   
 $y2 = 0.0014252$   
 $sh2 = 0.00456062$   
 $ft2 = 449.345$   
 $fy2 = 374.4542$   
 $su2 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/lb, min = 0.30798991$   
 $su2 = 0.4 \cdot esu2\_nominal \cdot ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs2 = (fs\_jacket \cdot Asl\_com\_jacket + fs\_core \cdot Asl\_com\_core) / Asl\_com = 374.4542$   
with  $Es2 = (Es\_jacket \cdot Asl\_com\_jacket + Es\_core \cdot Asl\_com\_core) / Asl\_com = 200000.00$   
 $yv = 0.0014252$   
 $shv = 0.00456062$   
 $ftv = 453.2097$   
 $fyv = 377.6747$   
 $suv = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/ld = 0.30798991$   
 $suv = 0.4 \cdot esuv\_nominal \cdot ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs\_jacket \cdot Asl\_mid\_jacket + fs\_mid \cdot Asl\_mid\_core) / Asl\_mid = 377.6747$   
with  $Es_v = (Es\_jacket \cdot Asl\_mid\_jacket + Es\_mid \cdot Asl\_mid\_core) / Asl\_mid = 200000.00$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.08977028$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.0456314$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.08124101$   
and confined core properties:  
 $b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.11029209$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.05606291$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.099813$   
Case/Assumption: Unconfined full section - Steel rupture  
'satisfies Eq. (4.3)  
--->  
 $v < vs, y2$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.2110448$   
 $Mu = MRc (4.14) = 8.0265E+008$   
 $u = su (4.1) = 9.7291088E-006$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.30798991$   
 $lb = 300.00$   
 $ld = 974.0579$

Calculation of  $I_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 655.558$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 0.8418647$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$$

$$n = 24.00$$

Calculation of  $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.9479397\text{E-}006$$

$$\mu_u = 4.8921\text{E+}008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha_0 \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} \cdot \text{Max}(\mu_u, \mu_c) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.01186911$$

$$\mu_u \text{ ((5.4c), TBDY)} = \alpha_{se} \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$$

where  $f = \alpha_f \cdot p_f \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L \cdot t \cdot \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\text{ase ((5.4d), TBDY)} = (\alpha_{se1} \cdot A_{\text{ext}} + \alpha_{se2} \cdot A_{\text{int}}) / A_{\text{sec}} = 0.11512199$$

$$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) \cdot (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 71100.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{NoConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 0.87336895$

Expression (5.4d) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 449.345

fy1 = 374.4542

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.30798991

su1 =  $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 374.4542$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y_2 = 0.0014252$   
 $sh_2 = 0.00456062$   
 $ft_2 = 455.1997$   
 $fy_2 = 379.3331$   
 $su_2 = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/lb_{u,min} = 0.30798991$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 379.3331$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 0.30798991$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02433675$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.04787748$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.04332854$

and confined core properties:

$b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.0276252$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05434683$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.04918322$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.14216778$   
 $Mu = MRc (4.14) = 4.8921E+008$   
 $u = su (4.1) = 8.9479397E-006$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.30798991$   
 $lb = 300.00$   
 $ld = 974.0579$   
 Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
 where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

#### Calculation of $\mu_2$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.7291088\text{E-}006$   
 $\mu = 8.0265\text{E+}008$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00174378$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha_1(5A.5, \text{TBDY}) = 0.002$   
 Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha_1) = 0.01186911$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\mu = 0.01186911$   
 $\mu_e(5.4c, \text{TBDY}) = \alpha_1 * \text{sh}_{\text{min}} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$   
 where  $f = \alpha_1 * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_f = 0.015$

$\alpha_{se}((5.4d), \text{TBDY}) = (\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}})/A_{\text{sec}} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and  
is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length  
equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2})*(A_{conf,min2}/A_{conf,max2}),0) = 0.12134906$   
The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization  
of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)  
"Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and  
is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and  
is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length  
equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min}*F_{ywe} = \text{Min}(psh_x*F_{ywe}, psh_y*F_{ywe}) = 0.87336895$   
Expression (5.4d) for  $psh_{min}*F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without  
earthquake detailing (90° closed stirrups)

-----  
 $psh_x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1 ((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 (5.4d) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548  
-----

-----  
 $psh_y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1 ((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548  
-----

-----  
 $A_{sec} = 440000.00$   
 $s1 = 510.00$   
 $s2 = 250.00$   
 $fy_{we1} = 694.45$   
 $fy_{we2} = 555.55$   
 $f_{ce} = 33.00$   
From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $y1 = 0.0014252$   
 $sh1 = 0.00456062$   
 $ft1 = 455.1997$   
 $fy1 = 379.3331$   
 $su1 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $su1 = 0.4*es_{u1\_nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $es_{u1\_nominal} = 0.08$ ,  
For calculation of  $es_{u1\_nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fs_{y1} = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25*(l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = (f_{s,jacket}*A_{s1,ten,jacket} + f_{s,core}*A_{s1,ten,core})/A_{s1,ten} = 379.3331$   
with  $Es1 = (E_{s,jacket}*A_{s1,ten,jacket} + E_{s,core}*A_{s1,ten,core})/A_{s1,ten} = 200000.00$   
 $y2 = 0.0014252$   
 $sh2 = 0.00456062$   
 $ft2 = 449.345$   
 $fy2 = 374.4542$   
 $su2 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor



and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 374.4542$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.08977028$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.0456314$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.08124101$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.11029209$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05606291$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2110448$

$Mu = MRc (4.14) = 8.0265E+008$

$u = su (4.1) = 9.7291088E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$

$l_b = 300.00$

$l_d = 974.0579$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 653603.866$

Calculation of Shear Strength at edge 1,  $V_{r1} = 653603.866$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 653603.866$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot \text{Area}_{jacket} + f'_{c\_core} \cdot \text{Area}_{core}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 140237.117$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 0.00$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.00$

$s/d = 1.59375$

$V_{s,j2} = 61600.349$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.60$

$s/d = 0.85$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78636.768$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), \text{ACI 440}) = 372533.843$

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $tf1 = NL \cdot t / NoDir = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 707.00  
 $ffe$  ((11-5), ACI 440) = 259.312  
 $Ef = 64828.00$   
 $fe = 0.004$ , from (11.6a), ACI 440  
 with  $fu = 0.01$   
 From (11-11), ACI 440:  $Vs + Vf \leq 838832.606$   
 $bw = 400.00$

Calculation of Shear Strength at edge 2,  $Vr2 = 653603.866$   
 $Vr2 = VCol$  ((10.3), ASCE 41-17) =  $knl \cdot VColO$   
 $VColO = 653603.866$   
 $knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $Vs = Av \cdot fy \cdot d / s$ ' is replaced by ' $Vs + f \cdot Vf$ '  
 where  $Vf$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $Mu = 11.78144$   
 $Vu = 0.00051441$   
 $d = 0.8 \cdot h = 600.00$   
 $Nu = 16273.616$   
 $Ag = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs_{jacket} + Vs_{core} = 140237.117$   
 where:  
 $Vs_{jacket} = Vs_{j1} + Vs_{j2} = 61600.349$   
 $Vs_{j1} = 0.00$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 510.00$   
 $Vs_{j1}$  is multiplied by  $Col_{j1} = 0.00$   
 $s/d = 1.59375$   
 $Vs_{j2} = 61600.349$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 510.00$   
 $Vs_{j2}$  is multiplied by  $Col_{j2} = 0.60$   
 $s/d = 0.85$   
 $Vs_{core} = Vs_{c1} + Vs_{c2} = 78636.768$   
 $Vs_{c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $Av = 100530.965$   
 $fy = 444.44$   
 $s = 250.00$   
 $Vs_{c1}$  is multiplied by  $Col_{c1} = 0.00$   
 $s/d = 1.5625$   
 $Vs_{c2} = 78636.768$  is calculated for section flange core, with:  
 $d = 440.00$   
 $Av = 100530.965$   
 $fy = 444.44$   
 $s = 250.00$   
 $Vs_{c2}$  is multiplied by  $Col_{c2} = 1.00$   
 $s/d = 0.56818182$   
 $Vf$  ((11-3)-(11.4), ACI 440) = 372533.843  
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $Vf( , )$ , is implemented for every different fiber orientation  $ai$ ,  
 as well as for 2 crack directions,  $= 45^\circ$  and  $= -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$   
 $df_v = d$  (figure 11.2, ACI 440) = 707.00  
 $ffe ((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$   
 $bw = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
 At local axis: 2  
 Integration Section: (a)  
 Section Type: rcjics

#### Constant Properties

Knowledge Factor,  $\gamma = 0.90$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_b = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $ef_u = 0.01$   
 Number of directions,  $\text{NoDir} = 1$   
 Fiber orientations,  $bi: 0.00^\circ$   
 Number of layers,  $NL = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -200080.825$

Shear Force, V2 = -5209.785  
 Shear Force, V3 = 97.60185  
 Axial Force, F = -16800.923  
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
     -Tension: Aslt = 0.00  
     -Compression: Aslc = 5353.274  
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
     -Tension: Asl,ten = 1137.257  
     -Compression: Asl,com = 2208.54  
     -Middle: Asl,mid = 2007.478  
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
     -Tension: Asl,ten,jacket = 829.3805  
     -Compression: Asl,com,jacket = 1746.726  
     -Middle: Asl,mid,jacket = 1545.664  
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
     -Tension: Asl,ten,core = 307.8761  
     -Compression: Asl,com,core = 461.8141  
     -Middle: Asl,mid,core = 461.8141  
 Mean Diameter of Tension Reinforcement, DbL = 16.80

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = \phi u = 0.00174766$   
 $u = y + p = 0.00194184$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00194184$  ((4.29), Biskinis Phd))  
 $M_y = 4.1179E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 2049.97  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4491E+014$   
 $factor = 0.30$   
 $A_g = 440000.00$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$   
 $N = 16800.923$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$   
 web width,  $b_w = 400.00$   
 flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 3.0742160E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 350.6021$   
 $d = 707.00$   
 $y = 0.19345095$   
 $A = 0.01018613$   
 $B = 0.00449653$   
 with  $p_t = 0.00376294$   
 $p_c = 0.00416509$   
 $p_v = 0.00378591$   
 $N = 16800.923$   
 $b = 750.00$   
 $\rho = 0.06082037$   
 $y_{comp} = 1.6463045E-005$   
 with  $f_c' (12.3, (ACI 440)) = 33.48734$   
 $f_c = 33.00$   
 $f_l = 0.49678681$

$b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $Ag = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $rc = 40.00$   
 $Ae/Ac = 0.31291181$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $\gamma = 0.19180888$   
 $A = 0.01002479$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $\gamma = 0.19276987 < t/d$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.38498739$

$l_b = 300.00$

$l_d = 779.2463$

Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \max(s_{external}, s_{internal}) = 510.00$

$n = 24.00$

- Calculation of  $p$  -

From table 10-8:  $p = 0.00$

with:

- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$

shear control ratio  $V_y E / V_{col} O E = 0.81868759$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00376294$

jacket:  $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.000721$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 510.00$

core:  $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00067082$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$  is implemented to account for FRP contribution

where  $f = 2 \cdot t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation  $f_s$  of jacket is used.

$NUD = 16800.923$

$Ag = 440000.00$

$f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section\_area = 27.68182$

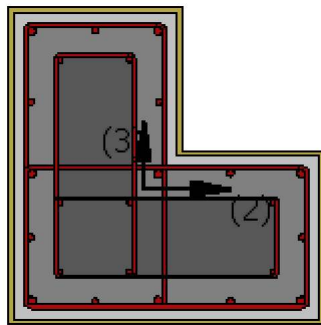
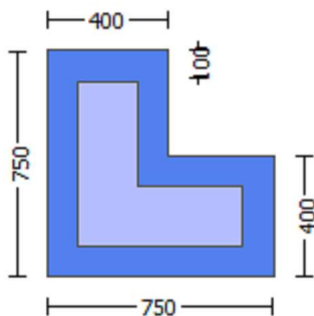
$f_{yIE} = (f_{y,ext\_Long\_Reinf} \cdot Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Reinf} = 529.9972$

$f_{tE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 502.0032$   
 $\rho_l = Area\_Tot\_Long\_Rein / (b \cdot d) = 0.01009575$   
 $b = 750.00$   
 $d = 707.00$   
 $f_{cE} = 27.68182$

-----  
 End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
 At local axis: 2  
 Integration Section: (a)

### Calculation No. 3

column C1, Floor 1  
 Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)  
 Analysis: Uniform +X  
 Check: Shear capacity  $V_{Rd}$   
 Edge: Start  
 Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1  
 At local axis: 3  
 Integration Section: (a)  
 Section Type: rcjls

Constant Properties

-----  
 Knowledge Factor,  $\gamma = 0.90$   
 Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.  
 Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
 Concrete Elasticity,  $E_c = 26999.444$

```

Steel Elasticity, Es = 200000.00
Existing Column
Existing material of Primary Member: Concrete Strength, fc = fc_lower_bound = 16.00
Existing material of Primary Member: Steel Strength, fs = fs_lower_bound = 400.00
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of  $\mu_y$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, fc = fcm = 33.00
New material: Steel Strength, fs = fsm = 555.56
Existing Column
Existing material: Concrete Strength, fc = fcm = 20.00
Existing material: Steel Strength, fs = fsm = 444.44
#####
Max Height, Hmax = 750.00
Min Height, Hmin = 400.00
Max Width, Wmax = 750.00
Min Width, Wmin = 400.00
Jacket Thickness, tj = 100.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length lo = lb = 300.00
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, ffu = 1055.00
Tensile Modulus, Ef = 64828.00
Elongation, efu = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

```

```

Stepwise Properties
-----
EDGE -A-
Bending Moment, Ma = -200080.825
Shear Force, Va = 97.60185
EDGE -B-
Bending Moment, Mb = -91261.79
Shear Force, Vb = -97.60185
BOTH EDGES
Axial Force, F = -16800.923
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 5353.274
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1137.257
-Compression: Asl,com = 2208.54
-Middle: Asl,mid = 2007.478
Mean Diameter of Tension Reinforcement, DbL,ten = 16.80
-----

```

```

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = *Vn = 579817.926
Vn ((10.3), ASCE 41-17) = knl*VCoIo = 644242.14

```



VCol = 644242.14

knl = 1.00

displacement\_ductility\_demand = 0.01284134

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 21.31818$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 3.41662$

$\mu_u = 200080.825$

$V_u = 97.60185$

$d = 0.8 \cdot h = 600.00$

$N_u = 16800.923$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 126213.67$

where:

$V_{s,jacket} = V_{sj1} + V_{sj2} = 55439.87$

$V_{sj1} = 55439.87$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 510.00$

$V_{sj1}$  is multiplied by  $Col,j1 = 0.60$

$s/d = 0.85$

$V_{sj2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 510.00$

$V_{sj2}$  is multiplied by  $Col,j2 = 0.00$

$s/d = 1.59375$

$V_{s,core} = V_{sc1} + V_{sc2} = 70773.799$

$V_{sc1} = 70773.799$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{sc1}$  is multiplied by  $Col,c1 = 1.00$

$s/d = 0.56818182$

$V_{sc2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{sc2}$  is multiplied by  $Col,c2 = 0.00$

$s/d = 1.5625$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 736127.561$

$b_w = 400.00$

displacement\_ductility\_demand is calculated as  $\delta / y$

- Calculation of  $\delta / y$  for END A -  
for rotation axis 2 and integ. section (a)

From analysis, chord rotation  $\theta = 2.4935843E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.00194184$  ((4.29), Biskinis Phd))

$M_y = 4.1179E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 2049.97

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 16800.923$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 3.0742160E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 350.6021$

$d = 707.00$

$y = 0.19345095$

$A = 0.01018613$

$B = 0.00449653$

with  $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 16800.923$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6463045E-005$

with  $f_c' (12.3, (ACI 440)) = 33.48734$

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e / A_c = 0.31291181$

Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$

effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19180888$

$A = 0.01002479$

$B = 0.00440616$

with  $E_s = 200000.00$

CONFIRMATION:  $y = 0.19276987 < t/d$

Calculation of ratio  $I_b / I_d$

Lap Length:  $I_d / I_{d,min} = 0.38498739$

lb = 300.00

ld = 779.2463

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 16.66667

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 0.8418647

Atr = Min(Atr\_x, Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s\_external, s\_internal) = 510.00

n = 24.00

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 4

column C1, Floor 1

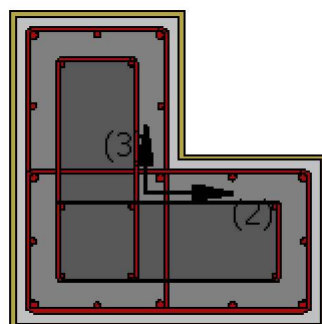
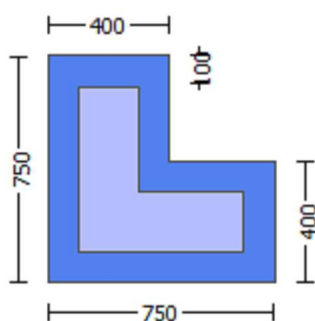
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\mu$  )

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlc

Constant Properties

Knowledge Factor,  $\phi = 0.90$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Jacket  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.03889  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 3  
 EDGE -A-  
 Shear Force,  $V_a = -0.00051441$   
 EDGE -B-  
 Shear Force,  $V_b = 0.00051441$   
 BOTH EDGES  
 Axial Force,  $F = -16273.616$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $As_t = 0.00$   
 -Compression:  $As_c = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten} = 1137.257$   
 -Compression:  $As_{l,com} = 2208.54$   
 -Middle:  $As_{l,mid} = 2007.478$

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.81868759$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$   
 with  
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 8.0265E+008$   
 $\mu_{1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
 which is defined for the static loading combination  
 $\mu_{1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
 direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 8.0265E+008$   
 $\mu_{2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
 which is defined for the the static loading combination  
 $\mu_{2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment  
 direction which is defined for the the static loading combination

Calculation of  $\mu_{1+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu = 8.9479397E-006$   
 $M_u = 4.8921E+008$

with full section properties:

$b = 750.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093001$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha (5A.5, \text{TB DY}) = 0.002$

Final value of  $\mu_c$ :  $\mu_c^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY:  $\mu_c = 0.01186911$

we ((5.4c), TB DY) =  $\alpha \epsilon_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$

where  $f = \alpha f_p f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{f,e} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{f,e} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u,f = 0.015$

ase ((5.4d), TB DY) =  $(\alpha \epsilon_1 * A_{\text{ext}} + \alpha \epsilon_2 * A_{\text{int}}) / A_{\text{sec}} = 0.11512199$

$\alpha \epsilon_1 = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 71100.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{NoConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 0.87336895$

Expression (5.4d) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.000721$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.000721$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 449.345

fy1 = 374.4542

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.30798991

su1 =  $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 374.4542$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y_2 = 0.0014252$   
 $sh_2 = 0.00456062$   
 $ft_2 = 455.1997$   
 $fy_2 = 379.3331$   
 $su_2 = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/lb_{u,min} = 0.30798991$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 379.3331$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 0.30798991$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02433675$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.04787748$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.04332854$

and confined core properties:

$b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.0276252$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05434683$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.04918322$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.14216778$   
 $Mu = MRc (4.14) = 4.8921E+008$   
 $u = su (4.1) = 8.9479397E-006$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.30798991$   
 $lb = 300.00$   
 $ld = 974.0579$   
 Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
 where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

#### Calculation of $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.7291088\text{E-}006$   
 $\mu_u = 8.0265\text{E+}008$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00174378$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha_1(5A.5, \text{TBDY}) = 0.002$

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.01186911$

we ((5.4c), TBDY) =  $\alpha_1 \cdot \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$

where  $f = \alpha_1 * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{u,f} = 0.015$

$\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and



is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and  
is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length  
equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2})*(A_{conf,min2}/A_{conf,max2}),0) = 0.12134906$   
The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization  
of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)  
"Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and  
is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and  
is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length  
equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min}*F_{ywe} = \text{Min}(psh_x*F_{ywe}, psh_y*F_{ywe}) = 0.87336895$   
Expression (5.4d) for  $psh_{min}*F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without  
earthquake detailing (90° closed stirrups)

-----  
 $psh_x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1 ((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548  
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 $psh_y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1 ((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548  
-----

-----  
 $A_{sec} = 440000.00$   
 $s1 = 510.00$   
 $s2 = 250.00$   
 $fy_{we1} = 694.45$   
 $fy_{we2} = 555.55$   
 $f_{ce} = 33.00$   
From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $y1 = 0.0014252$   
 $sh1 = 0.00456062$   
 $ft1 = 455.1997$   
 $fy1 = 379.3331$   
 $su1 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $su1 = 0.4*es_{u1\_nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $es_{u1\_nominal} = 0.08$ ,  
For calculation of  $es_{u1\_nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fs_{y1} = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25*(l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = (f_{s,jacket}*A_{s1,ten,jacket} + f_{s,core}*A_{s1,ten,core})/A_{s1,ten} = 379.3331$   
with  $Es1 = (E_{s,jacket}*A_{s1,ten,jacket} + E_{s,core}*A_{s1,ten,core})/A_{s1,ten} = 200000.00$   
 $y2 = 0.0014252$   
 $sh2 = 0.00456062$   
 $ft2 = 449.345$   
 $fy2 = 374.4542$   
 $su2 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.30798991$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 374.4542$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.08977028$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.0456314$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.08124101$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.11029209$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05606291$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2110448$

$Mu = MRc (4.14) = 8.0265E+008$

$u = su (4.1) = 9.7291088E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$

$l_b = 300.00$

$l_d = 974.0579$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

#### Calculation of $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.9479397\text{E-}006$$

$$\mu_{\mu} = 4.8921\text{E+}008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$c_o(5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, c_o) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01186911$$

$$\text{we ((5.4c), TBDY) } = a_{se} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se}((5.4d), \text{TBDY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.12134906$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  (5.4d) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$fywe1 = 694.45$

$fywe2 = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 449.345$

$fy1 = 374.4542$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.30798991$

$su1 = 0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket} \cdot A_{sl,ten,jacket} + fs_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 374.4542$

with  $Es1 = (Es_{jacket} \cdot A_{sl,ten,jacket} + Es_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 455.1997$

$fy2 = 379.3331$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{u,min} = lb/lb_{min} = 0.30798991$

$su2 = 0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y2$ ,  $sh2$ ,  $ft2$ ,  $fy2$ , it is considered

characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{s2} = (f_{sjacket} \cdot A_{sl,com,jacket} + f_{s,core} \cdot A_{sl,com,core}) / A_{sl,com} = 379.3331$   
with  $E_{s2} = (E_{sjacket} \cdot A_{sl,com,jacket} + E_{s,core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{sv} = (f_{sjacket} \cdot A_{sl,mid,jacket} + f_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 377.6747$   
with  $E_{sv} = (E_{sjacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.02433675$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.04787748$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.04332854$   
and confined core properties:  
 $b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0276252$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.05434683$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.04918322$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)  
--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.14216778$   
 $Mu = MRc (4.14) = 4.8921E+008$   
 $u = su (4.1) = 8.9479397E-006$   
-----  
Calculation of ratio  $l_b/l_d$   
-----  
Lap Length:  $l_b/l_d = 0.30798991$   
 $l_b = 300.00$   
 $l_d = 974.0579$   
Calculation of  $l_b,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1  
 $db = 16.66667$   
Mean strength value of all re-bars:  $fy = 655.558$   
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} < =$   
8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$   
-----  
-----  
-----

## Calculation of Mu2-

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 9.7291088E-006$$

$$M_u = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\phi_{co} (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_{cu}: \phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{co}) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01186911$$

$$\phi_{we} ((5.4c), TBDY) = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.04377629$$

where  $\phi_f = a_f * \phi_f^* * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\phi_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$a_{se1} = \text{Max}(((A_{conf, \max 1} - A_{noConf1}) / A_{conf, \max 1}) * (A_{conf, \min 1} / A_{conf, \max 1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf, \min 1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf, \max 1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf, \max 2} - A_{noConf2}) / A_{conf, \max 2}) * (A_{conf, \min 2} / A_{conf, \max 2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  (5.4d) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 455.1997$

$fy1 = 379.3331$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.30798991$

$su1 = 0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered

characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket} \cdot A_{sl,ten,jacket} + fs_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 379.3331$

with  $Es1 = (Es_{jacket} \cdot A_{sl,ten,jacket} + Es_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 449.345$

$fy2 = 374.4542$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{u,min} = lb/lb_{min} = 0.30798991$

$su2 = 0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y2$ ,  $sh2$ ,  $ft2$ ,  $fy2$ , it is considered

characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs_{jacket} \cdot A_{sl,com,jacket} + fs_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 374.4542$

with  $Es2 = (Es_{jacket} \cdot A_{sl,com,jacket} + Es_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$

$yv = 0.0014252$

$shv = 0.00456062$

```

ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 0.30798991
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^2/3), from 10.3.5, ASCE 41-17.
    with fsv = (fsjacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.08977028
    2 = Asl,com/(b*d)*(fs2/fc) = 0.0456314
    v = Asl,mid/(b*d)*(fsv/fc) = 0.08124101
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
    c = confinement factor = 1.03889
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.11029209
    2 = Asl,com/(b*d)*(fs2/fc) = 0.05606291
    v = Asl,mid/(b*d)*(fsv/fc) = 0.099813
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.2110448
Mu = MRc (4.14) = 8.0265E+008
u = su (4.1) = 9.7291088E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.30798991
lb = 300.00
ld = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 0.8418647
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 510.00
n = 24.00
-----
-----
-----
Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 653603.866
-----
Calculation of Shear Strength at edge 1, Vr1 = 653603.866
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 653603.866

```



knl = 1 (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77537$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 140237.117$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 61600.349$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $Col,j1 = 0.60$

$s/d = 0.85$

$V_{s,j2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $Col,j2 = 0.00$

$s/d = 1.59375$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 78636.768$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$

$s/d = 1.5625$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,

where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_{fe} = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$

$b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $knl \cdot V_{ColO}$

VColO = 653603.866

kn1 = 1 (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77482$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 140237.117$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 61600.349$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.60$

$s/d = 0.85$

$V_{s,j2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.00$

$s/d = 1.59375$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 78636.768$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 0.00$

$s/d = 1.5625$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $\theta_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$

$b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjlc

#### Constant Properties

Knowledge Factor,  $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.03889

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -0.00051441$

EDGE -B-

Shear Force,  $V_b = 0.00051441$

BOTH EDGES

Axial Force,  $F = -16273.616$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1137.257$

-Compression:  $As_{c,com} = 2208.54$

-Middle:  $As_{c,mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.81868759$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 8.0265E+008$

$Mu_{1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 8.0265E+008$

$Mu_{2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $Mu_{1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 8.9479397E-006$

$M_u = 4.8921E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

$\phi_{co} (5A.5, TBDY) = 0.002$

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01186911$

we ((5.4c), TBDY)  $= a_s e * \phi_{u,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.04377629$

where  $\phi_f = a_f * \phi_p * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area  $= ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_p = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$\phi_{fy} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area  $= ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00508$   
 $bw = 400.00$   
effective stress from (A.35),  $ff,e = 870.5244$

R = 40.00

Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.11512199$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.11081094$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 0.87336895$

Expression (5.4d) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 0.87336895$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 0.87336895$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 449.345$

$fy1 = 374.4542$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.30798991$   
 $su1 = 0.4*esu1\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
For calculation of  $esu1\_nominal$  and  $y1, sh1,ft1,fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1,ft1,fy1$ , are also multiplied by  $Min(1,1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 374.4542$   
with  $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$   
 $y2 = 0.0014252$   
 $sh2 = 0.00456062$   
 $ft2 = 455.1997$   
 $fy2 = 379.3331$   
 $su2 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lou,min = lb/lb,min = 0.30798991$   
 $su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
For calculation of  $esu2\_nominal$  and  $y2, sh2,ft2,fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1,ft1,fy1$ , are also multiplied by  $Min(1,1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 379.3331$   
with  $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$   
 $yv = 0.0014252$   
 $shv = 0.00456062$   
 $ftv = 453.2097$   
 $fyv = 377.6747$   
 $suv = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.30798991$   
 $suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $yv, shv,ftv,fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1,ft1,fy1$ , are also multiplied by  $Min(1,1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747$   
with  $Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854$   
and confined core properties:  
 $b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)  
--->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.14216778$   
 $Mu = MRc (4.14) = 4.8921E+008$   
 $u = su (4.1) = 8.9479397E-006$

#### Calculation of ratio $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$

$l_b = 300.00$

$l_d = 974.0579$

Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$

$n = 24.00$

#### Calculation of $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.7291088\text{E-}006$

$\mu_u = 8.0265\text{E+}008$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00174378$

$N = 16273.616$

$f_c = 33.00$

$\phi_c$  (5A.5, TBDY) = 0.002

Final value of  $\phi_c$ :  $\phi_c^* = \text{shear\_factor} \cdot \text{Max}(\phi_c, \phi_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_c = 0.01186911$

we ((5.4c), TBDY) =  $\phi_c^* \cdot \text{sh}_{\text{min}} \cdot f_{ywe}/f_{ce} + \text{Min}(\phi_c, \phi_y) = 0.04377629$

where  $\phi_c^* = \phi_c^* \cdot p_f \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_c = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\phi_c = 1 - (\text{Unconfined area})/(\text{total area})$

$\phi_c = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$\phi_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\phi_y = 1 - (\text{Unconfined area})/(\text{total area})$

$\phi_y = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = NL \cdot t \cdot \text{Cos}(\theta_1) = 1.016$

$$f_u, f = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.11512199$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2(5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 510.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0014252$$

$$sh1 = 0.00456062$$

$$ft1 = 455.1997$$

$$fy1 = 379.3331$$

$$su1 = 0.00542681$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lo_{u,min} = l_b/l_d = 0.30798991$$

$$su1 = 0.4 * esu1_{nominal}((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,



For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 379.3331$

with  $Es1 = (Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 449.345$

$fy2 = 374.4542$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lou,min = lb/lb,min = 0.30798991$

$su2 = 0.4 \cdot esu2\_nominal \cdot ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 374.4542$

with  $Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

$yv = 0.0014252$

$shv = 0.00456062$

$ftv = 453.2097$

$fyv = 377.6747$

$suv = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lou,min = lb/ld = 0.30798991$

$suv = 0.4 \cdot esuv\_nominal \cdot ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 377.6747$

with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.08977028$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.0456314$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.08124101$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.11029209$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.05606291$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2110448$

$Mu = MRc (4.14) = 8.0265E+008$

$u = su (4.1) = 9.7291088E-006$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.30798991$

$lb = 300.00$

$ld = 974.0579$

Calculation of  $lb,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\gamma = 1$   
 $d_b = 16.66667$   
Mean strength value of all re-bars:  $f_y = 655.558$   
Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $c_b = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$   
where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \max(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$

#### Calculation of $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu = 8.9479397E-006$   
 $\mu_u = 4.8921E+008$

with full section properties:

$b = 750.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093001$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha (5A.5, TBDY) = 0.002$   
Final value of  $\mu$ :  $\mu^* = shear\_factor \cdot \max(\mu, \mu_c) = 0.01186911$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\mu = 0.01186911$   
we ((5.4c), TBDY) =  $ase \cdot sh_{min} \cdot f_{ywe} / f_{ce} + \min(f_x, f_y) = 0.04377629$   
where  $f = af \cdot pf \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$$af = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff_e = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$$af = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff_e = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL \cdot t \cdot \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.11512199$$

$$ase1 = \max(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 449.345$

$fy1 = 374.4542$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{min} = lb/l_d = 0.30798991$

$su1 = 0.4 * esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered

characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 374.4542$

with  $Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.0014252$

```

sh2 = 0.00456062
ft2 = 455.1997
fy2 = 379.3331
su2 = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/lb,min = 0.30798991
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
    with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 379.3331
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
    yv = 0.0014252
    shv = 0.00456062
    ftv = 453.2097
    fyv = 377.6747
    suv = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/lb = 0.30798991
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
    2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
    v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.30798991
lb = 300.00
ld = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00

```

$s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
 where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

Calculation of  $\mu_2$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.7291088E-006$   
 $\mu_u = 8.0265E+008$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00174378$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha_1(5A.5, \text{TB DY}) = 0.002$   
 Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01186911$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TB DY:  $\mu_c = 0.01186911$   
 $\mu_{cc}((5.4c), \text{TB DY}) = \alpha_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$   
 where  $f = \alpha_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$\alpha_{se}((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 71100.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 0.87336895$

Expression (5.4d) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 455.1997

fy1 = 379.3331

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min =  $l_b/l_d = 0.30798991$

su1 =  $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 379.3331$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.0014252

sh2 = 0.00456062

ft2 = 449.345

fy2 = 374.4542

su2 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 374.4542$   
 with  $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.08977028$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.0456314$   
 $v = A_{sl,mid} / (b * d) * (fs_v / fc) = 0.08124101$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.11029209$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.05606291$   
 $v = A_{sl,mid} / (b * d) * (fs_v / fc) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2110448$

$Mu = MRc (4.14) = 8.0265E+008$

$u = su (4.1) = 9.7291088E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$

$l_b = 300.00$

$l_d = 974.0579$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = Min(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 653603.866$

Calculation of Shear Strength at edge 1,  $V_{r1} = 653603.866$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 653603.866$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_{s+} + f \cdot V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.68182$ , but  $f'_c^{0.5} < = 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 140237.117$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 0.00$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.00$

$s/d = 1.59375$

$V_{s,j2} = 61600.349$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.60$

$s/d = 0.85$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78636.768$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 372533.843$

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,

where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$



$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe}$  ((11-5), ACI 440) = 259.312  
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$   
 $b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 653603.866$   
 $k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '  
 where  $V_f$  is the contribution of FRPs ((11.3), ACI 440).

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f'_c^{0.5} \leq 8.3$  MPa ((22.5.3.1, ACI 318-14))  
 $M/Vd = 4.00$   
 $\mu_u = 11.78144$   
 $V_u = 0.00051441$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.616$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 140237.117$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 61600.349$   
 $V_{s,j1} = 0.00$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 0.00$   
 $s/d = 1.59375$   
 $V_{s,j2} = 61600.349$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 0.60$   
 $s/d = 0.85$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 78636.768$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 372533.843  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$   
 $b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1

At local axis: 3  
Integration Section: (a)  
Section Type: rcjlc

Constant Properties

Knowledge Factor,  $\gamma = 0.90$   
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_b = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $\text{NoDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

Stepwise Properties

Bending Moment,  $M = -1.5690\text{E}+007$   
Shear Force,  $V_2 = -5209.785$

Shear Force,  $V_3 = 97.60185$   
 Axial Force,  $F = -16800.923$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
     -Tension:  $As_{lt} = 0.00$   
     -Compression:  $As_{lc} = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
     -Tension:  $As_{l,ten} = 1137.257$   
     -Compression:  $As_{l,com} = 2208.54$   
     -Middle:  $As_{l,mid} = 2007.478$   
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
     -Tension:  $As_{l,ten,jacket} = 829.3805$   
     -Compression:  $As_{l,com,jacket} = 1746.726$   
     -Middle:  $As_{l,mid,jacket} = 1545.664$   
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
     -Tension:  $As_{l,ten,core} = 307.8761$   
     -Compression:  $As_{l,com,core} = 461.8141$   
     -Middle:  $As_{l,mid,core} = 461.8141$   
 Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $\phi_{u,R} = \phi_u = 0.00256752$   
 $\phi_u = \phi_y + \phi_p = 0.0028528$

- Calculation of  $\phi_y$  -

$\phi_y = (M_y \cdot L_s / 3) / E_{eff} = 0.0028528$  ((4.29), Biskinis Phd)  
 $M_y = 4.1179E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3011.65  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 1.4491E+014$   
 $factor = 0.30$   
 $A_g = 440000.00$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$   
 $N = 16800.923$   
 $E_c \cdot I_g = E_{c,jacket} \cdot I_{g,jacket} + E_{c,core} \cdot I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\phi_y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$   
 web width,  $b_w = 400.00$   
 flange thickness,  $t = 400.00$

$y = \min(\phi_{y,ten}, \phi_{y,com})$   
 $\phi_{y,ten} = 3.0742160E-006$   
 with ((10.1), ASCE 41-17)  $\phi_y = \min(\phi_y, 1.25 \cdot \phi_y \cdot (I_b/I_d)^{2/3}) = 350.6021$   
 $d = 707.00$   
 $\phi_y = 0.19345095$   
 $A = 0.01018613$   
 $B = 0.00449653$   
 with  $p_t = 0.00376294$   
 $p_c = 0.00416509$   
 $p_v = 0.00378591$   
 $N = 16800.923$   
 $b = 750.00$   
 $\phi_y = 0.06082037$   
 $\phi_{y,comp} = 1.6463045E-005$   
 with  $f'_c \cdot (12.3, (ACI 440)) = 33.48734$   
 $f'_c = 33.00$   
 $\phi_l = 0.49678681$   
 $b = b_{max} = 750.00$

$h = h_{max} = 750.00$   
 $A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $rc = 40.00$   
 $A_e/A_c = 0.31291181$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $\gamma = 0.19180888$   
 $A = 0.01002479$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $\gamma = 0.19276987 < t/d$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.38498739$   
 $l_b = 300.00$   
 $l_d = 779.2463$

Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 524.4464$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \max(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$

- Calculation of  $p$  -

From table 10-8:  $p = 0.00$

with:

- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$   
 shear control ratio  $V_y E / V_{col} E = 0.81868759$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00376294$

jacket:  $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.000721$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 510.00$

core:  $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00067082$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$  is implemented to account for FRP contribution

where  $f = 2 \cdot t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation  $f_s$  of jacket is used.

$NUD = 16800.923$

$A_g = 440000.00$

$f_{cE} = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / section\_area = 27.68182$

$f_{yE} = (f_{y,ext\_Long\_Reinf} \cdot Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 529.9972$

$f_{tE} = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 502.0032$

$pl = \text{Area\_Tot\_Long\_Rein}/(b*d) = 0.01009575$

$b = 750.00$

$d = 707.00$

$f_{cE} = 27.68182$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 5

column C1, Floor 1

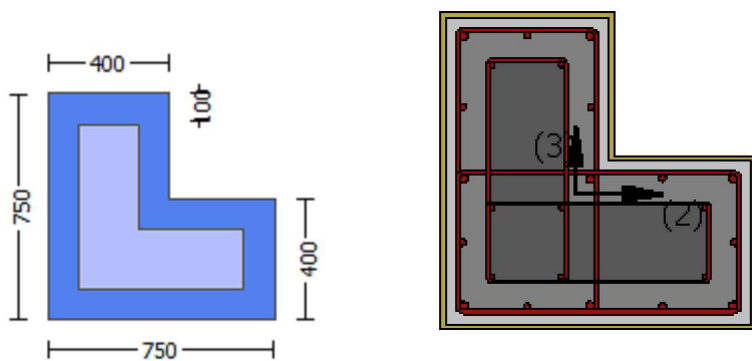
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjls

Constant Properties

Knowledge Factor,  $\gamma = 0.90$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

```

Existing Column
Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$ 
Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$ 
Concrete Elasticity,  $E_c = 21019.039$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material: Steel Strength,  $f_s = f_{sm} = 555.56$ 
Existing Column
Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$ 
Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$ 
#####
Max Height,  $H_{max} = 750.00$ 
Min Height,  $H_{min} = 400.00$ 
Max Width,  $W_{max} = 750.00$ 
Min Width,  $W_{min} = 400.00$ 
Jacket Thickness,  $t_j = 100.00$ 
Cover Thickness,  $c = 25.00$ 
Element Length,  $L = 3000.00$ 
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length  $l_o = l_b = 300.00$ 
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $NoDir = 1$ 
Fiber orientations,  $bi: 0.00^\circ$ 
Number of layers,  $NL = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
EDGE -A-
Bending Moment,  $M_a = -1.5690E+007$ 
Shear Force,  $V_a = -5209.785$ 
EDGE -B-
Bending Moment,  $M_b = 56787.791$ 
Shear Force,  $V_b = 5209.785$ 
BOTH EDGES
Axial Force,  $F = -16800.923$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $As_t = 0.00$ 
-Compression:  $As_c = 5353.274$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $As_{l,ten} = 1137.257$ 
-Compression:  $As_{l,com} = 2208.54$ 
-Middle:  $As_{l,mid} = 2007.478$ 
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$ 
-----

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity  $V_R = \phi V_n = 684441.513$ 
 $V_n$  ((10.3), ASCE 41-17) =  $k_n l V_{CoI} = 760490.57$ 
 $V_{CoI} = 760490.57$ 

```

kn1 = 1.00  
displacement\_ductility\_demand = 0.05755874

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)  
Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 21.31818$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 56787.791$   
 $V_u = 5209.785$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16800.923$   
 $A_g = 300000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 126213.67$   
where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 55439.87$   
 $V_{s,j1} = 0.00$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 510.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 0.00$   
 $s/d = 1.59375$   
 $V_{s,j2} = 55439.87$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 510.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 0.60$   
 $s/d = 0.85$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 70773.799$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 400.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 70773.799$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 400.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 372533.843  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
where  $a$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe}$  ((11-5), ACI 440) = 259.312  
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 736127.561$   
 $b_w = 400.00$

displacement\_ductility\_demand is calculated as  $\delta / y$

- Calculation of  $\delta / y$  for END B -  
for rotation axis 3 and integ. section (b)

From analysis, chord rotation  $\theta = 1.6356814E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.00028418$  ((4.29), Biskinis Phd))

$M_y = 4.1179E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 16800.923$

$E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 3.0742160E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 350.6021$

$d = 707.00$

$y = 0.19345095$

$A = 0.01018613$

$B = 0.00449653$

with  $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 16800.923$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6463045E-005$

with  $f_c' (12.3, (ACI 440)) = 33.48734$

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e / A_c = 0.31291181$

Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$

effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19180888$

$A = 0.01002479$

$B = 0.00440616$

with  $E_s = 200000.00$

CONFIRMATION:  $y = 0.19276987 < t/d$

Calculation of ratio  $I_b / I_d$

Lap Length:  $I_d / I_{d,min} = 0.38498739$

$I_b = 300.00$



ld = 779.2463

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 524.4464

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 0.8418647

Atr = Min(Atr\_x, Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s\_external, s\_internal) = 510.00

n = 24.00

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 6

column C1, Floor 1

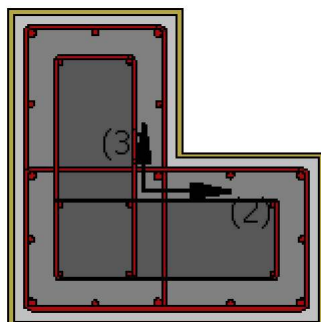
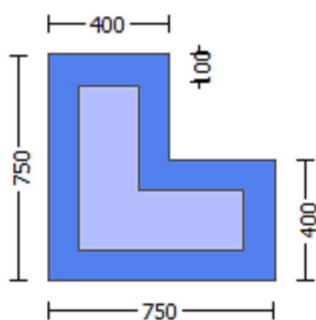
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( u)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlc

Constant Properties

Knowledge Factor,  $\phi = 0.90$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
#####  
Note: Especially for the calculation of moment strengths,  
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
Jacket  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
Existing Column  
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.03889  
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$   
-----

#### Stepwise Properties

-----  
At local axis: 3  
EDGE -A-  
Shear Force,  $V_a = -0.00051441$   
EDGE -B-  
Shear Force,  $V_b = 0.00051441$   
BOTH EDGES  
Axial Force,  $F = -16273.616$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 5353.274$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 1137.257$   
-Compression:  $As_{l,com} = 2208.54$   
-Middle:  $As_{l,mid} = 2007.478$   
-----  
-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.81868759$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$   
 with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.0265E+008$   
 $M_{u1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
 which is defined for the static loading combination  
 $M_{u1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
 direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.0265E+008$   
 $M_{u2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
 which is defined for the the static loading combination  
 $M_{u2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment  
 direction which is defined for the the static loading combination

-----  
 Calculation of  $M_{u1+}$   
 -----

-----  
 Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 8.9479397E-006$

$M_u = 4.8921E+008$   
 -----

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

$\phi_c$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01186911$

$\phi_{we}$  ((5.4c), TBDY) =  $a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.04377629$

where  $\phi_f = a_f * \phi_p * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $\phi_{fx} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$   
 -----

$\phi_{fy} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$   
 -----

$R = 40.00$

Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

$a_{se}$  ((5.4d), TBDY) =  $(a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.11512199$

$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 449.345$

$fy1 = 374.4542$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30798991$

$su1 = 0.4 * esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered

characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 374.4542$

with  $Es1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0014252$

```

sh2 = 0.00456062
ft2 = 455.1997
fy2 = 379.3331
su2 = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/lb,min = 0.30798991
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
    with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 379.3331
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
    yv = 0.0014252
    shv = 0.00456062
    ftv = 453.2097
    fyv = 377.6747
    suv = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/lb = 0.30798991
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
    2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
    v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.30798991
lb = 300.00
lb = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00

```

$s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
 where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

Calculation of  $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.7291088E-006$   
 $\mu_1 = 8.0265E+008$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00174378$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha_1(5A.5, \text{TB DY}) = 0.002$

Final value of  $\mu_1$ :  $\mu_1^* = \text{shear\_factor} * \text{Max}(\mu_1, \mu_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY:  $\mu_1 = 0.01186911$

we ((5.4c), TB DY) =  $\alpha_1 * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$

where  $f = \alpha_1 * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $\rho_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $\rho_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$\alpha_{se}((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 71100.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 0.87336895$

Expression (5.4d) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 455.1997

fy1 = 379.3331

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min =  $l_b/l_d = 0.30798991$

su1 =  $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 379.3331$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.0014252

sh2 = 0.00456062

ft2 = 449.345

fy2 = 374.4542

su2 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 374.4542$   
 with  $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.08977028$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.0456314$   
 $v = A_{sl,mid} / (b * d) * (fs_v / fc) = 0.08124101$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.11029209$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.05606291$   
 $v = A_{sl,mid} / (b * d) * (fs_v / fc) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2110448$

$Mu = MRc (4.14) = 8.0265E+008$

$u = su (4.1) = 9.7291088E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$

$l_b = 300.00$

$l_d = 974.0579$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = Min(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis



s = Max(s\_external,s\_internal) = 510.00  
n = 24.00

#### Calculation of Mu2+

Calculation of ultimate curvature  $\kappa_u$  according to 4.1, Biskinis/Fardis 2013:

$\kappa_u = 8.9479397\text{E-}006$

$M_u = 4.8921\text{E+}008$

with full section properties:

b = 750.00

d = 707.00

d' = 43.00

$\nu = 0.00093001$

N = 16273.616

f<sub>c</sub> = 33.00

$\alpha_{co}$  (5A.5, TBDY) = 0.002

Final value of  $\alpha_{cu}$ :  $\alpha_{cu} = \text{shear\_factor} * \text{Max}(\alpha_{cu}, \alpha_{cc}) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\alpha_{cu} = 0.01186911$

$\alpha_{ve}$  ((5.4c), TBDY) =  $\alpha_{se} * \text{sh\_min} * f_{ywe}/f_{ce} + \text{Min}(\alpha_{fx}, \alpha_{fy}) = 0.04377629$

where  $\alpha_f = \alpha_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\alpha_{fx} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$\alpha_{fy} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

R = 40.00

Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\alpha_{u,f} = 0.015$

$\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}})/A_{\text{sec}} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\alpha_{se2} (>= \alpha_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 0.87336895$

Expression (5.4d) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 0.87336895$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  (5.4d) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 0.87336895$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 449.345$

$fy1 = 374.4542$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30798991$

$su1 = 0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} \cdot A_{sl,ten,jacket} + f_{s,core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 374.4542$

with  $Es1 = (E_{s,jacket} \cdot A_{sl,ten,jacket} + E_{s,core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 455.1997$

$fy2 = 379.3331$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$

$su2 = 0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y2$ ,  $sh2$ ,  $ft2$ ,  $fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

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y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $fs_2 = (fs_{jacket} \cdot A_{sl,com,jacket} + fs_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 379.3331$ 
with  $Es_2 = (Es_{jacket} \cdot A_{sl,com,jacket} + Es_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$ 
yv = 0.0014252
shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min =  $l_b/l_d = 0.30798991$ 
suv =  $0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$ 
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY
For calculation of  $esuv_{nominal}$  and yv, shv,ftv,fyv, it is considered
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.
with  $fsv = (fs_{jacket} \cdot A_{sl,mid,jacket} + fs_{mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 377.6747$ 
with  $Es_v = (Es_{jacket} \cdot A_{sl,mid,jacket} + Es_{mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$ 
1 =  $A_{sl,ten} / (b \cdot d) \cdot (fs_1/f_c) = 0.02433675$ 
2 =  $A_{sl,com} / (b \cdot d) \cdot (fs_2/f_c) = 0.04787748$ 
v =  $A_{sl,mid} / (b \cdot d) \cdot (fsv/f_c) = 0.04332854$ 
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 =  $A_{sl,ten} / (b \cdot d) \cdot (fs_1/f_c) = 0.0276252$ 
2 =  $A_{sl,com} / (b \cdot d) \cdot (fs_2/f_c) = 0.05434683$ 
v =  $A_{sl,mid} / (b \cdot d) \cdot (fsv/f_c) = 0.04918322$ 
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006
-----

Calculation of ratio  $l_b/l_d$ 
-----
Lap Length:  $l_b/l_d = 0.30798991$ 
lb = 300.00
ld = 974.0579
Calculation of  $l_b,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars:  $f_y = 655.558$ 
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq$ 
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 0.8418647
Atr =  $\text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$ 
where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis
s =  $\text{Max}(s_{external}, s_{internal}) = 510.00$ 
n = 24.00
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Calculation of Mu2-

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Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 9.7291088E-006$$

$$\mu_u = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\phi_{co} (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01186911$$

$$\phi_{we} ((5.4c), TBDY) = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.04377629$$

where  $\phi_f = a_f * \phi_{pf} * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\phi_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.12134906$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max2}} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh,min*F_{ywe} = \text{Min}(psh,x*F_{ywe}, psh,y*F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh,min*F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

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$psh_x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $Lstir1*Astir1/(Asec*s1) = 0.000721$   
 $Lstir1$  (Length of stirrups along Y) = 2060.00  
 $Astir1$  (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $Lstir2*Astir2/(Asec*s2) = 0.00067082$   
 $Lstir2$  (Length of stirrups along Y) = 1468.00  
 $Astir2$  (stirrups area) = 50.26548

---

$psh_y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $Lstir1*Astir1/(Asec*s1) = 0.000721$   
 $Lstir1$  (Length of stirrups along X) = 2060.00  
 $Astir1$  (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $Lstir2*Astir2/(Asec*s2) = 0.00067082$   
 $Lstir2$  (Length of stirrups along X) = 1468.00  
 $Astir2$  (stirrups area) = 50.26548

---

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 455.1997

fy1 = 379.3331

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.30798991

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket}*A_{s1,ten,jacket} + f_{s,core}*A_{s1,ten,core})/A_{s1,ten} = 379.3331$

with Es1 =  $(E_{s,jacket}*A_{s1,ten,jacket} + E_{s,core}*A_{s1,ten,core})/A_{s1,ten} = 200000.00$

y2 = 0.0014252

sh2 = 0.00456062

ft2 = 449.345

fy2 = 374.4542

su2 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30798991

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 =  $(f_{s,jacket}*A_{s1,com,jacket} + f_{s,core}*A_{s1,com,core})/A_{s1,com} = 374.4542$

with Es2 =  $(E_{s,jacket}*A_{s1,com,jacket} + E_{s,core}*A_{s1,com,core})/A_{s1,com} = 200000.00$

yv = 0.0014252

shv = 0.00456062

ftv = 453.2097

```

fyv = 377.6747
suv = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lo,min = lb/ld = 0.30798991
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = (fsjacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.08977028
2 = Asl,com/(b*d)*(fs2/fc) = 0.0456314
v = Asl,mid/(b*d)*(fsv/fc) = 0.08124101
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11029209
2 = Asl,com/(b*d)*(fs2/fc) = 0.05606291
v = Asl,mid/(b*d)*(fsv/fc) = 0.099813
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.2110448
Mu = MRc (4.14) = 8.0265E+008
u = su (4.1) = 9.7291088E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.30798991
lb = 300.00
ld = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 0.8418647
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 510.00
n = 24.00
-----

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 653603.866
-----
Calculation of Shear Strength at edge 1, Vr1 = 653603.866
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO
VColO = 653603.866
knl = 1 (zero step-static loading)

```

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77537$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 140237.117$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 61600.349$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.60$

$s/d = 0.85$

$V_{s,j2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.00$

$s/d = 1.59375$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 78636.768$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 0.00$

$s/d = 1.5625$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$

$b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$

$V_{r2} = V_{\text{Col}}((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 653603.866$

knl = 1 (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77482$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 140237.117$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 61600.349$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.60$

$s/d = 0.85$

$V_{s,j2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.00$

$s/d = 1.59375$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 78636.768$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 0.00$

$s/d = 1.5625$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,

where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\alpha)$ , is implemented for every different fiber orientation  $\alpha_i$ , as well as for 2 crack directions,  $\alpha = 45^\circ$  and  $\alpha = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\alpha_1 = \alpha_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$

$b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At local axis: 3



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjlc

#### Constant Properties

Knowledge Factor,  $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.03889

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -0.00051441$

EDGE -B-

Shear Force,  $V_b = 0.00051441$

BOTH EDGES

Axial Force,  $F = -16273.616$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $As_t = 0.00$   
   -Compression:  $As_c = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $As_{t,ten} = 1137.257$   
   -Compression:  $As_{c,com} = 2208.54$   
   -Middle:  $As_{mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.81868759$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$   
 with  
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 8.0265E+008$   
 $Mu_{1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $Mu_{1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 8.0265E+008$   
 $Mu_{2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination  
 $Mu_{2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $Mu_{1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 8.9479397E-006$   
 $M_u = 4.8921E+008$

with full section properties:

$b = 750.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093001$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\phi_{cc} \text{ (5A.5, TBDY)} = 0.002$

Final value of  $\phi_{cu}$ :  $\phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_{cu} = 0.01186911$

we ((5.4c), TBDY)  $= a_s e * \phi_{u,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.04377629$

where  $\phi_{fx} = a_f * \phi_{pf} * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area  $= ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$\phi_{fy} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area  $= ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_{pf} = 2t_f/b_w = 0.00508$

bw = 400.00  
effective stress from (A.35),  $f_{f,e} = 870.5244$

R = 40.00

Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

$ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.11512199$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 0.87336895$

Expression (5.4d) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 0.87336895$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 0.87336895$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 449.345$

$fy1 = 374.4542$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,  
For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_1 = (fs_{jacket} * Asl_{ten,jacket} + fs_{core} * Asl_{ten,core}) / Asl_{ten} = 374.4542$   
with  $Es_1 = (Es_{jacket} * Asl_{ten,jacket} + Es_{core} * Asl_{ten,core}) / Asl_{ten} = 200000.00$   
 $y_2 = 0.0014252$   
 $sh_2 = 0.00456062$   
 $ft_2 = 455.1997$   
 $fy_2 = 379.3331$   
 $su_2 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 379.3331$   
with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 377.6747$   
with  $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02433675$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.04787748$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.04332854$   
and confined core properties:  
 $b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.0276252$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05434683$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.04918322$   
Case/Assumption: Unconfined full section - Steel rupture  
'satisfies Eq. (4.3)  
--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.14216778$   
 $Mu = MRc (4.14) = 4.8921E+008$   
 $u = su (4.1) = 8.9479397E-006$

-----  
Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$   
 $l_b = 300.00$   
 $l_d = 974.0579$   
 Calculation of  $l_b$ , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$

Calculation of  $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu = 9.7291088E-006$   
 $\mu_u = 8.0265E+008$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00174378$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha_1 (5A.5, \text{TB DY}) = 0.002$   
 Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} \cdot \text{Max}(\mu_u, \mu_c) = 0.01186911$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TB DY:  $\mu_u = 0.01186911$   
 we ((5.4c), TB DY) =  $\alpha_1 \cdot \text{sh}_{\min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$   
 where  $f = \alpha_1 \cdot p_f \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.11512199$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2(5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 510.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0014252$$

$$sh1 = 0.00456062$$

$$ft1 = 455.1997$$

$$fy1 = 379.3331$$

$$su1 = 0.00542681$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30798991$$

$$su1 = 0.4 * esu1_{nominal}((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{nominal} = 0.08,$$

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered

characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 379.3331$   
with  $E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 200000.00$   
 $y2 = 0.0014252$   
 $sh2 = 0.00456062$   
 $ft2 = 449.345$   
 $fy2 = 374.4542$   
 $su2 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.30798991$   
 $su2 = 0.4 \cdot esu2_{nominal} ((5.5), \text{TBDY}) = 0.032$   
From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,  
For calculation of  $esu2_{nominal}$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 374.4542$   
with  $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core})/A_{s,com} = 200000.00$   
 $yv = 0.0014252$   
 $shv = 0.00456062$   
 $ftv = 453.2097$   
 $fyv = 377.6747$   
 $suv = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), \text{TBDY}) = 0.032$   
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 377.6747$   
with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$   
 $1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.08977028$   
 $2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0456314$   
 $v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08124101$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, \text{TBDY}) = 34.2833$   
 $cc (5A.5, \text{TBDY}) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.11029209$   
 $2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.05606291$   
 $v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2110448$   
 $Mu = MRc (4.14) = 8.0265E+008$   
 $u = su (4.1) = 9.7291088E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$   
 $l_b = 300.00$   
 $l_d = 974.0579$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

$db = 16.66667$   
Mean strength value of all re-bars:  $fy = 655.558$   
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$

Calculation of  $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 8.9479397E-006$

$\mu_u = 4.8921E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$fc = 33.00$

$\alpha$  (5A.5, TBDY) = 0.002

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} \cdot \text{Max}(\mu_u, \mu_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.01186911$

we ((5.4c), TBDY) =  $\alpha \cdot s \cdot \min(f_{ywe}/f_{ce} + \text{Min}(f_x, f_y)) = 0.04377629$

where  $f = \alpha \cdot p_f \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$fy = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).



The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)  
"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and  
is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and  
is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length  
equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization  
of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)  
"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and  
is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and  
is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length  
equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without  
earthquake detailing (90° closed stirrups)

-----  
 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 449.345$

$fy1 = 374.4542$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{u,min} = lb/l_d = 0.30798991$

$su1 = 0.4 * esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered

characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 374.4542$

with  $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

```

ft2 = 455.1997
fy2 = 379.3331
su2 = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.30798991
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
    with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 379.3331
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
    yv = 0.0014252
    shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.30798991
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
    2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
    v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854
and confined core properties:
    b = 690.00
    d = 677.00
    d' = 13.00
    fcc (5A.2, TBDY) = 34.2833
    cc (5A.5, TBDY) = 0.00238888
    c = confinement factor = 1.03889
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
    2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
    v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

```

```

---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->

```

```

su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.30798991
lb = 300.00
lb = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80

```

$e = 1.00$   
 $cb = 25.00$   
 $Ktr = 0.8418647$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

Calculation of  $\mu_2$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu = 9.7291088E-006$   
 $\mu_u = 8.0265E+008$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00174378$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha (5A.5, \text{TB DY}) = 0.002$   
 Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01186911$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TB DY:  $\mu_c = 0.01186911$   
 $\mu_{cc} ((5.4c), \text{TB DY}) = \alpha s_e * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$   
 where  $f = \alpha f_p * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = NL * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$\alpha s_e ((5.4d), \text{TB DY}) = (\alpha s_{e1} * A_{\text{ext}} + \alpha s_{e2} * A_{\text{int}}) / A_{\text{sec}} = 0.11512199$

$\alpha s_{e1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 71100.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i/6$  as defined at (A.2).  
psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 0.87336895$

Expression (5.4d) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d)) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 455.1997

fy1 = 379.3331

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min =  $l_b / l_d = 0.30798991$

su1 =  $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 379.3331$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.0014252

sh2 = 0.00456062

ft2 = 449.345

fy2 = 374.4542

su2 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30798991$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 374.4542$   
 with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.08977028$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.0456314$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.08124101$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.11029209$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05606291$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

---->

$su (4.9) = 0.2110448$

$\mu_u = MR_c (4.14) = 8.0265E+008$

$u = su (4.1) = 9.7291088E-006$

-----  
 Calculation of ratio  $l_b/l_d$   
 -----

Lap Length:  $l_b/l_d = 0.30798991$

$l_b = 300.00$

$l_d = 974.0579$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 510.00$

$$n = 24.00$$

$$\text{Calculation of Shear Strength } V_r = \text{Min}(V_{r1}, V_{r2}) = 653603.866$$

$$\text{Calculation of Shear Strength at edge 1, } V_{r1} = 653603.866$$

$$V_{r1} = V_{\text{Col}} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{\text{ColO}}$$

$$V_{\text{ColO}} = 653603.866$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 11.78089$$

$$V_u = 0.00051441$$

$$d = 0.8 \cdot h = 600.00$$

$$N_u = 16273.616$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 140237.117$$

where:

$$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 61600.349$$

$V_{s,j1} = 0.00$  is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 510.00$$

$$V_{s,j1} \text{ is multiplied by } \text{Col},j1 = 0.00$$

$$s/d = 1.59375$$

$V_{s,j2} = 61600.349$  is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 510.00$$

$$V_{s,j2} \text{ is multiplied by } \text{Col},j2 = 0.60$$

$$s/d = 0.85$$

$$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78636.768$$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 250.00$$

$$V_{s,c1} \text{ is multiplied by } \text{Col},c1 = 0.00$$

$$s/d = 1.5625$$

$V_{s,c2} = 78636.768$  is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 250.00$$

$$V_{s,c2} \text{ is multiplied by } \text{Col},c2 = 1.00$$

$$s/d = 0.56818182$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 372533.843$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \theta = b1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 707.00$$

$f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$   
 $b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$   
 $V_{Col0} = 653603.866$   
 $k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 11.78144$   
 $V_u = 0.00051441$   
 $d = 0.8 * h = 600.00$   
 $N_u = 16273.616$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 140237.117$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 61600.349$   
 $V_{s,j1} = 0.00$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 0.00$   
 $s/d = 1.59375$   
 $V_{s,j2} = 61600.349$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 0.60$   
 $s/d = 0.85$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 78636.768$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$

dfv = d (figure 11.2, ACI 440) = 707.00  
ffe ((11-5), ACI 440) = 259.312  
Ef = 64828.00  
fe = 0.004, from (11.6a), ACI 440  
with fu = 0.01  
From (11-11), ACI 440: Vs + Vf <= 838832.606  
bw = 400.00

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
At local axis: 2  
Integration Section: (b)  
Section Type: rcjls

#### Constant Properties

Knowledge Factor,  $\gamma = 0.90$   
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_b = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $bi = 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -91261.79$   
Shear Force,  $V_2 = 5209.785$   
Shear Force,  $V_3 = -97.60185$



Axial Force,  $F = -16800.923$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
     -Tension:  $As_t = 0.00$   
     -Compression:  $As_c = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
     -Tension:  $As_{t,ten} = 1137.257$   
     -Compression:  $As_{c,com} = 2208.54$   
     -Middle:  $As_{mid} = 2007.478$   
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
     -Tension:  $As_{t,ten,jacket} = 829.3805$   
     -Compression:  $As_{c,com,jacket} = 1746.726$   
     -Middle:  $As_{mid,jacket} = 1545.664$   
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
     -Tension:  $As_{t,ten,core} = 307.8761$   
     -Compression:  $As_{c,com,core} = 461.8141$   
     -Middle:  $As_{mid,core} = 461.8141$   
 Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $\phi_R = \phi_u = 0.00079715$   
 $\phi_u = \phi_y + \phi_p = 0.00088572$

- Calculation of  $\phi_y$  -

$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00088572$  ((4.29), Biskinis Phd))  
 $M_y = 4.1179E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 935.0416  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4491E+014$   
 $factor = 0.30$   
 $A_g = 440000.00$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.68182$   
 $N = 16800.923$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\phi_y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $\phi_y < t/d$ , compression zone rectangular) with:  
 flange width,  $b = 750.00$   
 web width,  $b_w = 400.00$   
 flange thickness,  $t = 400.00$

$\phi_y = \text{Min}(\phi_{y,ten}, \phi_{y,com})$   
 $\phi_{y,ten} = 3.0742160E-006$   
 with ((10.1), ASCE 41-17)  $\phi_y = \text{Min}(\phi_y, 1.25 * \phi_y * (I_b / I_d)^{2/3}) = 350.6021$   
 $d = 707.00$   
 $\phi_y = 0.19345095$   
 $A = 0.01018613$   
 $B = 0.00449653$   
 with  $p_t = 0.00376294$   
 $p_c = 0.00416509$   
 $p_v = 0.00378591$   
 $N = 16800.923$   
 $b = 750.00$   
 $\phi_y = 0.06082037$   
 $\phi_{y,comp} = 1.6463045E-005$   
 with  $f'_c$  (12.3, (ACI 440)) = 33.48734  
 $f'_c = 33.00$   
 $f_l = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$

$A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $rc = 40.00$   
 $A_e/A_c = 0.31291181$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $\gamma = 0.19180888$   
 $A = 0.01002479$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $\gamma = 0.19276987 < t/d$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.38498739$   
 $l_b = 300.00$   
 $l_d = 779.2463$   
 Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 524.4464$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \max(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$

- Calculation of  $p$  -

From table 10-8:  $p = 0.00$

with:

- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$

shear control ratio  $V_y E / V_{col} E = 0.81868759$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00376294$

jacket:  $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.000721$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 510.00$

core:  $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00067082$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$  is implemented to account for FRP contribution

where  $f = 2 \cdot t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation  $f_s$  of jacket is used.

$NUD = 16800.923$

$A_g = 440000.00$

$f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section\_area = 27.68182$

$f_{yIE} = (f_{y,ext\_Long\_Reinf} \cdot Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 529.9972$

$f_{yIE} = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 502.0032$

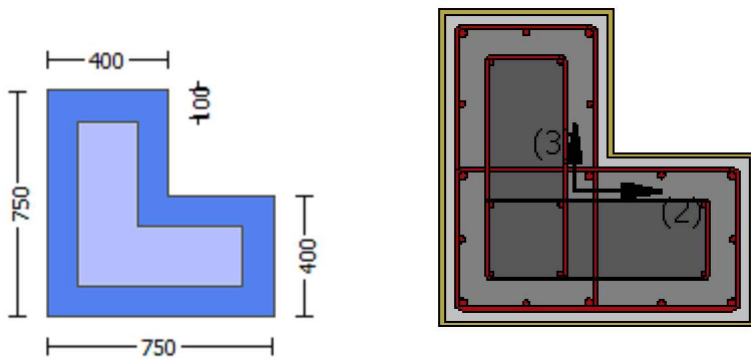
$p_l = Area_{Tot\_Long\_Rein} / (b \cdot d) = 0.01009575$

b = 750.00  
d = 707.00  
f<sub>cE</sub> = 27.68182

-----  
End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
At local axis: 2  
Integration Section: (b)  
-----

## Calculation No. 7

column C1, Floor 1  
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)  
Analysis: Uniform +X  
Check: Shear capacity VR<sub>d</sub>  
Edge: End  
Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
Section Type: rcjcs

Constant Properties

-----  
Knowledge Factor,  $\gamma = 0.90$   
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.  
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
#####  
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,  
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as  
Deformation-Controlled Action (Table C7-1, ASCE 41-17).  
Jacket  
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
Existing Column  
Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = l_b = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $bi: 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$   
-----  
Stepwise Properties  
-----  
EDGE -A-  
Bending Moment,  $M_a = -200080.825$   
Shear Force,  $V_a = 97.60185$   
EDGE -B-  
Bending Moment,  $M_b = -91261.79$   
Shear Force,  $V_b = -97.60185$   
BOTH EDGES  
Axial Force,  $F = -16800.923$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 5353.274$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 1137.257$   
-Compression:  $As_{c,com} = 2208.54$   
-Middle:  $As_{mid} = 2007.478$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$   
-----  
-----  
Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = *V_n = 684441.513$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{ColO} = 760490.57$   
 $V_{Col} = 760490.57$   
 $knl = 1.00$

displacement\_ductility\_demand = 3.3964651E-005

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 21.31818$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 91261.79$

$V_u = 97.60185$

$d = 0.8 \cdot h = 600.00$

$N_u = 16800.923$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 126213.67$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 55439.87$

$V_{s,j1} = 55439.87$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $Col,j1 = 0.60$

$s/d = 0.85$

$V_{s,j2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $Col,j2 = 0.00$

$s/d = 1.59375$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 70773.799$

$V_{s,c1} = 70773.799$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$

$s/d = 1.5625$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,

where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 736127.561$

$b_w = 400.00$

displacement\_ductility\_demand is calculated as  $\delta / y$

- Calculation of  $\phi_y$  for END B -  
for rotation axis 2 and integ. section (b)

From analysis, chord rotation  $\theta = 3.0083216E-008$

$y = (M_y * L_s / 3) / E_{eff} = 0.00088572$  ((4.29), Biskinis Phd))

$M_y = 4.1179E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 935.0416

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 16800.923$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\phi_y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 3.0742160E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 350.6021$

$d = 707.00$

$y = 0.19345095$

$A = 0.01018613$

$B = 0.00449653$

with  $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 16800.923$

$b = 750.00$

$\alpha = 0.06082037$

$y_{comp} = 1.6463045E-005$

with  $f_c' (12.3, (ACI 440)) = 33.48734$

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e / A_c = 0.31291181$

Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$

effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19180888$

$A = 0.01002479$

$B = 0.00440616$

with  $E_s = 200000.00$

CONFIRMATION:  $y = 0.19276987 < t/d$

Calculation of ratio  $I_b / I_d$

Lap Length:  $I_d / I_{d,min} = 0.38498739$

$I_b = 300.00$

$I_d = 779.2463$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 16.66667

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 0.8418647

Atr = Min(Atr\_x, Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s\_external, s\_internal) = 510.00

n = 24.00

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 8

column C1, Floor 1

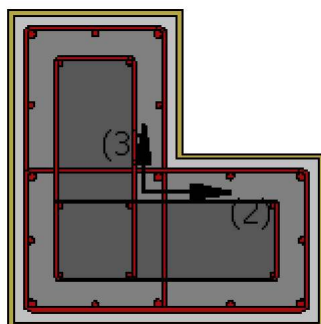
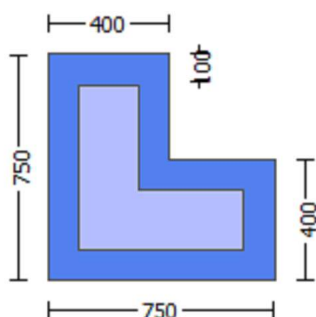
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( u)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlc

Constant Properties

Knowledge Factor, = 0.90

Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Jacket  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.03889  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$   
 -----

#### Stepwise Properties

-----

At local axis: 3  
 EDGE -A-  
 Shear Force,  $V_a = -0.00051441$   
 EDGE -B-  
 Shear Force,  $V_b = 0.00051441$   
 BOTH EDGES  
 Axial Force,  $F = -16273.616$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $As_t = 0.00$   
   -Compression:  $As_c = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $As_{t,ten} = 1137.257$   
   -Compression:  $As_{l,com} = 2208.54$   
   -Middle:  $As_{l,mid} = 2007.478$   
 -----  
 -----



Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.81868759$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 8.0265E+008$

$\mu_{1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 8.0265E+008$

$\mu_{2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

-----  
Calculation of  $\mu_{1+}$   
-----

-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 8.9479397E-006$

$M_u = 4.8921E+008$   
-----

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

$\alpha_0$  (5A.5, TBDY) = 0.002

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_s) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_c = 0.01186911$

$\mu_s$  ((5.4c), TBDY) =  $\alpha_{se} * \mu_{s0} * \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.04377629$

where  $f = \alpha_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$   
-----

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$   
-----

$R = 40.00$

Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

$\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.11081094$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)  
 "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and  
 is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and  
 is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length  
 equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization  
 of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)  
 "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and  
 is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and  
 is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length  
 equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without  
 earthquake detailing (90° closed stirrups)

-----  
 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 449.345$

$fy1 = 374.4542$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00

$lo/lo_{u,min} = l_b/l_d = 0.30798991$

$su1 = 0.4 * esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 374.4542$

with  $Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

```

ft2 = 455.1997
fy2 = 379.3331
su2 = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.30798991
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
    with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 379.3331
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
    yv = 0.0014252
    shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.30798991
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
    2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
    v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
    2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
    v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

```

```

---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->

```

```

su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.30798991
lb = 300.00
lb = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80

```

$e = 1.00$   
 $cb = 25.00$   
 $Ktr = 0.8418647$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

Calculation of  $Mu1$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 9.7291088E-006$   
 $Mu = 8.0265E+008$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00174378$   
 $N = 16273.616$   
 $fc = 33.00$   
 $co(5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01186911$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01186911$   
 $we(5.4c, TBDY) = ase * sh_{\text{min}} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.04377629$   
 where  $f = af * pf * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$fx = 0.04286225$   
 Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
 $af = 0.31984848$   
 with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$   
 $b_{\text{max}} = 750.00$   
 $h_{\text{max}} = 750.00$   
 From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$   
 $bw = 400.00$   
 effective stress from (A.35),  $ff_e = 870.5244$

$fy = 0.04286225$   
 Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
 $af = 0.31984848$   
 with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$   
 $b_{\text{max}} = 750.00$   
 $h_{\text{max}} = 750.00$   
 From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$   
 $bw = 400.00$   
 effective stress from (A.35),  $ff_e = 870.5244$

$R = 40.00$   
 Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$   
 $fu, f = 1055.00$   
 $Ef = 64828.00$   
 $u, f = 0.015$   
 $ase(5.4d), TBDY = (ase1 * A_{\text{ext}} + ase2 * A_{\text{int}})/A_{\text{sec}} = 0.11512199$   
 $ase1 = \text{Max}(((A_{\text{conf, max1}} - A_{\text{noConf1}})/A_{\text{conf, max1}}) * (A_{\text{conf, min1}}/A_{\text{conf, max1}}), 0) = 0.11081094$   
 The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf, min}}$  and  $A_{\text{conf, max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{\text{conf, max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{\text{conf, min1}} = 71100.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 0.87336895$

Expression (5.4d) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d)) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 455.1997

fy1 = 379.3331

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.30798991

su1 =  $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered

characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 379.3331$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.0014252

sh2 = 0.00456062

ft2 = 449.345

fy2 = 374.4542

su2 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30798991$   
 $s_u2 = 0.4 \cdot e_{su2\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{su2\_nominal} = 0.08$ ,  
 For calculation of  $e_{su2\_nominal}$  and  $y_2$ ,  $sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{s2} = (f_{s,jacket} \cdot A_{sl,com,jacket} + f_{s,core} \cdot A_{sl,com,core}) / A_{sl,com} = 374.4542$   
 with  $E_{s2} = (E_{s,jacket} \cdot A_{sl,com,jacket} + E_{s,core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $s_{uv} = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.30798991$   
 $s_{uv} = 0.4 \cdot e_{suv\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{suv\_nominal} = 0.08$ ,  
 considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $e_{suv\_nominal}$  and  $y_v$ ,  $sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{sv} = (f_{s,jacket} \cdot A_{sl,mid,jacket} + f_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 377.6747$   
 with  $E_{sv} = (E_{s,jacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1}/f_c) = 0.08977028$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2}/f_c) = 0.0456314$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv}/f_c) = 0.08124101$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1}/f_c) = 0.11029209$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2}/f_c) = 0.05606291$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv}/f_c) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

---->

$s_u (4.9) = 0.2110448$

$\mu_u = M_{Rc} (4.14) = 8.0265E+008$

$u = s_u (4.1) = 9.7291088E-006$

-----  
 Calculation of ratio  $l_b/l_d$   
 -----

Lap Length:  $l_b/l_d = 0.30798991$

$l_b = 300.00$

$l_d = 974.0579$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.68182$ , but  $f_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 510.00$

n = 24.00

#### Calculation of Mu2+

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.9479397\text{E-}006$$

$$Mu = 4.8921\text{E+}008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, c_o) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01186911$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = a_{se} * \mu_{min} * f_{ywe} / f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.04377629$$

where  $\mu = a_f * \mu_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\mu_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (\geq a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 0.87336895$

Expression (5.4d) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 0.87336895$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{s2}$  (5.4d) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 0.87336895$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{s2}$  ((5.4d), TBDY) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s_1 = 510.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y_1 = 0.0014252$

$sh_1 = 0.00456062$

$ft_1 = 449.345$

$fy_1 = 374.4542$

$su_1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30798991$

$su_1 = 0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (f_{s,jacket} \cdot A_{sl,ten,jacket} + f_{s,core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 374.4542$

with  $Es_1 = (E_{s,jacket} \cdot A_{sl,ten,jacket} + E_{s,core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.0014252$

$sh_2 = 0.00456062$

$ft_2 = 455.1997$

$fy_2 = 379.3331$

$su_2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$

$su_2 = 0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.



```

with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 379.3331
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0014252
shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.30798991
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.30798991
lb = 300.00
ld = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 0.8418647
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 510.00
n = 24.00

```

Calculation of Mu2-

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 9.7291088E-006$$

$$\mu = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\phi_0 (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_0) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01186911$$

$$\phi_{we} ((5.4c), \text{TBDY}) = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.04377629$$

where  $\phi_{fx} = a_f * \phi_{pf} * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\phi_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} ((5.4d), \text{TBDY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$a_{se1} = \text{Max}(((A_{\text{conf}, \max 1} - A_{\text{noConf1}}) / A_{\text{conf}, \max 1}) * (A_{\text{conf}, \min 1} / A_{\text{conf}, \max 1}), 0) = 0.11081094$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf}, \min}$  and  $A_{\text{conf}, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf}, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf}, \min 1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf}, \max 1}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf}, \max 2} - A_{\text{noConf2}}) / A_{\text{conf}, \max 2}) * (A_{\text{conf}, \min 2} / A_{\text{conf}, \max 2}), 0) = 0.12134906$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf}, \min}$  and  $A_{\text{conf}, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf}, \max 2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{\text{conf}, \min 2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $bi^2/6$  as defined at (A.2).

$psh_{min} \cdot Fywe = \min(psh_x \cdot Fywe, psh_y \cdot Fywe) = 0.87336895$

Expression (5.4d) for  $psh_{min} \cdot Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_x \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 0.87336895$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.000721$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ (5.4d)} = Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$   
 -----

-----  
 $psh_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 0.87336895$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.000721$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$   
 -----

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 455.1997

fy1 = 379.3331

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30798991

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered  
 characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\min(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 379.3331

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0014252

sh2 = 0.00456062

ft2 = 449.345

fy2 = 374.4542

su2 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30798991

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered  
 characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\min(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 374.4542

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.0014252

shv = 0.00456062

ftv = 453.2097

fyv = 377.6747

```

suv = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.30798991
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = (fsjacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.08977028
2 = Asl,com/(b*d)*(fs2/fc) = 0.0456314
v = Asl,mid/(b*d)*(fsv/fc) = 0.08124101
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11029209
2 = Asl,com/(b*d)*(fs2/fc) = 0.05606291
v = Asl,mid/(b*d)*(fsv/fc) = 0.099813
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.2110448
Mu = MRc (4.14) = 8.0265E+008
u = su (4.1) = 9.7291088E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.30798991
lb = 300.00
ld = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 0.8418647
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 510.00
n = 24.00
-----

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 653603.866
-----
Calculation of Shear Strength at edge 1, Vr1 = 653603.866
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO
VColO = 653603.866
knl = 1 (zero step-static loading)
-----

```

NOTE: In expression (10-3) ' $V_s = A_v f_y d/s$ ' is replaced by ' $V_s + f V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_c \text{ jacket} \cdot \text{Area}_{\text{jacket}} + f'_c \text{ core} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77537$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 140237.117$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 61600.349$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.60$

$s/d = 0.85$

$V_{s,j2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.00$

$s/d = 1.59375$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 78636.768$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 0.00$

$s/d = 1.5625$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,

where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$

$b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$

$V_{r2} = V_{\text{Col}}((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 653603.866$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77482$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 140237.117$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 61600.349$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.60$

$s/d = 0.85$

$V_{s,j2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.00$

$s/d = 1.59375$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 78636.768$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 0.00$

$s/d = 1.5625$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$

$b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjls

Constant Properties

Knowledge Factor,  $\gamma = 0.90$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Jacket  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.03889  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2  
 EDGE -A-  
 Shear Force,  $V_a = -0.00051441$   
 EDGE -B-  
 Shear Force,  $V_b = 0.00051441$   
 BOTH EDGES  
 Axial Force,  $F = -16273.616$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1137.257$

-Compression:  $As_{c,com} = 2208.54$

-Middle:  $As_{mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.81868759$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$

with

$M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 8.0265E+008$

$\mu_{u1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 8.0265E+008$

$\mu_{u2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $\mu_{u1+}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$\mu_u = 8.9479397E-006$

$\mu_u = 4.8921E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

$\alpha_0$  (5A.5, TBDY) = 0.002

Final value of  $\alpha_0$ :  $\alpha_0^* = \text{shear\_factor} * \max(\alpha_0, \alpha_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\alpha_0 = 0.01186911$

$\alpha_0$  ((5.4c), TBDY) =  $\alpha_0 * \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.04377629$

where  $f = \alpha_f * \rho_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $\rho_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $\rho_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$



effective stress from (A.35),  $f_{f,e} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$ase((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.11512199$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (\geq ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 0.87336895$

Expression (5.4d) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 0.87336895$

$p_{sh1}((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}((5.4d)) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 0.87336895$

$p_{sh1}((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}((5.4d), TBDY) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s_1 = 510.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y_1 = 0.0014252$

$sh_1 = 0.00456062$

$ft_1 = 449.345$

$fy_1 = 374.4542$

$su_1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with

$\text{Shear\_factor} = 1.00$   
 $\text{lo/lou,min} = \text{lb/l}_d = 0.30798991$   
 $\text{su}_1 = 0.4 * \text{esu1\_nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $\text{esu1\_nominal} = 0.08$ ,  
 For calculation of  $\text{esu1\_nominal}$  and  $y_1, \text{sh}_1, \text{ft}_1, \text{fy}_1$ , it is considered  
 characteristic value  $\text{fsy}_1 = \text{fs}_1/1.2$ , from table 5.1, TBDY.  
 $y_1, \text{sh}_1, \text{ft}_1, \text{fy}_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (\text{lb}/\text{l}_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $\text{fs}_1 = (\text{fs}_{\text{jacket}} * \text{Asl,ten,jacket} + \text{fs}_{\text{core}} * \text{Asl,ten,core}) / \text{Asl,ten} = 374.4542$   
 with  $\text{Es}_1 = (\text{Es}_{\text{jacket}} * \text{Asl,ten,jacket} + \text{Es}_{\text{core}} * \text{Asl,ten,core}) / \text{Asl,ten} = 200000.00$   
 $y_2 = 0.0014252$   
 $\text{sh}_2 = 0.00456062$   
 $\text{ft}_2 = 455.1997$   
 $\text{fy}_2 = 379.3331$   
 $\text{su}_2 = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with  $\text{shear\_factor}$   
 and also multiplied by the  $\text{shear\_factor}$  according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $\text{lo/lou,min} = \text{lb}/\text{lb,min} = 0.30798991$   
 $\text{su}_2 = 0.4 * \text{esu2\_nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $\text{esu2\_nominal} = 0.08$ ,  
 For calculation of  $\text{esu2\_nominal}$  and  $y_2, \text{sh}_2, \text{ft}_2, \text{fy}_2$ , it is considered  
 characteristic value  $\text{fsy}_2 = \text{fs}_2/1.2$ , from table 5.1, TBDY.  
 $y_2, \text{sh}_2, \text{ft}_2, \text{fy}_2$ , are also multiplied by  $\text{Min}(1, 1.25 * (\text{lb}/\text{l}_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $\text{fs}_2 = (\text{fs}_{\text{jacket}} * \text{Asl,com,jacket} + \text{fs}_{\text{core}} * \text{Asl,com,core}) / \text{Asl,com} = 379.3331$   
 with  $\text{Es}_2 = (\text{Es}_{\text{jacket}} * \text{Asl,com,jacket} + \text{Es}_{\text{core}} * \text{Asl,com,core}) / \text{Asl,com} = 200000.00$   
 $y_v = 0.0014252$   
 $\text{sh}_v = 0.00456062$   
 $\text{ft}_v = 453.2097$   
 $\text{fy}_v = 377.6747$   
 $\text{suv} = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with  $\text{shear\_factor}$   
 and also multiplied by the  $\text{shear\_factor}$  according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $\text{lo/lou,min} = \text{lb}/\text{l}_d = 0.30798991$   
 $\text{suv} = 0.4 * \text{esuv\_nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $\text{esuv\_nominal} = 0.08$ ,  
 considering characteristic value  $\text{fsy}_v = \text{fs}_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $\text{esuv\_nominal}$  and  $y_v, \text{sh}_v, \text{ft}_v, \text{fy}_v$ , it is considered  
 characteristic value  $\text{fsy}_v = \text{fs}_v/1.2$ , from table 5.1, TBDY.  
 $y_1, \text{sh}_1, \text{ft}_1, \text{fy}_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (\text{lb}/\text{l}_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $\text{fs}_v = (\text{fs}_{\text{jacket}} * \text{Asl,mid,jacket} + \text{fs}_{\text{mid}} * \text{Asl,mid,core}) / \text{Asl,mid} = 377.6747$   
 with  $\text{Es}_v = (\text{Es}_{\text{jacket}} * \text{Asl,mid,jacket} + \text{Es}_{\text{mid}} * \text{Asl,mid,core}) / \text{Asl,mid} = 200000.00$   
 $1 = \text{Asl,ten}/(\text{b} * \text{d}) * (\text{fs}_1/\text{fc}) = 0.02433675$   
 $2 = \text{Asl,com}/(\text{b} * \text{d}) * (\text{fs}_2/\text{fc}) = 0.04787748$   
 $v = \text{Asl,mid}/(\text{b} * \text{d}) * (\text{fs}_v/\text{fc}) = 0.04332854$

and confined core properties:

$b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $\text{fcc} (5A.2, \text{TBDY}) = 34.2833$   
 $\text{cc} (5A.5, \text{TBDY}) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = \text{Asl,ten}/(\text{b} * \text{d}) * (\text{fs}_1/\text{fc}) = 0.0276252$   
 $2 = \text{Asl,com}/(\text{b} * \text{d}) * (\text{fs}_2/\text{fc}) = 0.05434683$   
 $v = \text{Asl,mid}/(\text{b} * \text{d}) * (\text{fs}_v/\text{fc}) = 0.04918322$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{sy2}$  - LHS eq.(4.5) is satisfied

--->

$\text{su} (4.9) = 0.14216778$   
 $\text{Mu} = \text{MRc} (4.14) = 4.8921\text{E}+008$   
 $u = \text{su} (4.1) = 8.9479397\text{E}-006$

Calculation of ratio  $\text{lb}/\text{l}_d$

Lap Length:  $l_b/l_d = 0.30798991$

$l_b = 300.00$

$l_d = 974.0579$

Calculation of  $l_b$ , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$

$n = 24.00$

Calculation of  $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.7291088\text{E-}006$

$\mu_u = 8.0265\text{E+}008$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00174378$

$N = 16273.616$

$f_c = 33.00$

$\alpha_0$  (5A.5, TBDY) = 0.002

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} \cdot \text{Max}(\mu_u, \mu_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.01186911$

we ((5.4c), TBDY) =  $\alpha_{se} \cdot \text{sh}_{\text{min}} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$

where  $f = \alpha_f \cdot p_f \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = N L^* t \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$   
 $ase \text{ ((5.4d), TBDY)} = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.11512199$   
 $ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$   
 Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$   
 $psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$   
 $psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$   
 $s1 = 510.00$   
 $s2 = 250.00$   
 $fy_{we1} = 694.45$   
 $fy_{we2} = 555.55$   
 $f_{ce} = 33.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$   
 $c$  = confinement factor = 1.03889  
 $y1 = 0.0014252$   
 $sh1 = 0.00456062$   
 $ft1 = 455.1997$   
 $fy1 = 379.3331$   
 $su1 = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $lo/lo_{min} = lb/ld = 0.30798991$   
 $su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,  
 For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = (fs_{jacket} \cdot A_{s,ten,jacket} + fs_{core} \cdot A_{s,ten,core}) / A_{s,ten} = 379.3331$   
 with  $Es_1 = (Es_{jacket} \cdot A_{s,ten,jacket} + Es_{core} \cdot A_{s,ten,core}) / A_{s,ten} = 200000.00$   
 $y_2 = 0.0014252$   
 $sh_2 = 0.00456062$   
 $ft_2 = 449.345$   
 $fy_2 = 374.4542$   
 $su_2 = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.30798991$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} \cdot A_{s,com,jacket} + fs_{core} \cdot A_{s,com,core}) / A_{s,com} = 374.4542$   
 with  $Es_2 = (Es_{jacket} \cdot A_{s,com,jacket} + Es_{core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} \cdot A_{s,mid,jacket} + fs_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} \cdot A_{s,mid,jacket} + Es_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / f_c) = 0.08977028$   
 $2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / f_c) = 0.0456314$   
 $v = A_{s,mid} / (b \cdot d) \cdot (fs_v / f_c) = 0.08124101$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, \text{TBDY}) = 34.2833$   
 $cc (5A.5, \text{TBDY}) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / f_c) = 0.11029209$   
 $2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / f_c) = 0.05606291$   
 $v = A_{s,mid} / (b \cdot d) \cdot (fs_v / f_c) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2110448$

$\mu_u = M_{Rc} (4.14) = 8.0265E+008$

$u = su (4.1) = 9.7291088E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$

$l_b = 300.00$

$l_d = 974.0579$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$   
Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

Calculation of  $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu = 8.9479397E-006$   
 $\mu = 4.8921E+008$

with full section properties:

$b = 750.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093001$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha (5A.5, \text{TB DY}) = 0.002$   
Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} \cdot \text{Max}(\mu, \alpha) = 0.01186911$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TB DY:  $\mu = 0.01186911$   
we ((5.4c), TB DY) =  $\alpha \cdot \text{sh}_{\text{min}} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$   
where  $f = \alpha \cdot p_f \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = N L \cdot t \cdot \cos(b_1) = 1.016$

$f_u, f = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$

$\alpha_{se}$  ((5.4d), TB DY) =  $(\alpha_{se1} \cdot A_{\text{ext}} + \alpha_{se2} \cdot A_{\text{int}}) / A_{\text{sec}} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{\text{conf}, \text{max}1} - A_{\text{noConf}1}) / A_{\text{conf}, \text{max}1}) \cdot (A_{\text{conf}, \text{min}1} / A_{\text{conf}, \text{max}1}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf}, \text{min}}$  and  $A_{\text{conf}, \text{max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 0.87336895$

Expression (5.4d) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 0.87336895$   
 $p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 0.87336895$   
 $p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 440000.00$

$s_1 = 510.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y_1 = 0.0014252$

$sh_1 = 0.00456062$

$ft_1 = 449.345$

$fy_1 = 374.4542$

$su_1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30798991$

$su_1 = 0.4 * esu_{1,nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fs_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 374.4542$

with  $Es_1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y_2 = 0.0014252$

$sh_2 = 0.00456062$

$ft_2 = 455.1997$

```

fy2 = 379.3331
su2 = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.30798991
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 379.3331
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0014252
shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.30798991
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322

```

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

```

--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006

```

#### Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.30798991
lb = 300.00
lb = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc',jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00

```



$cb = 25.00$   
 $Ktr = 0.8418647$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

Calculation of  $\mu_2$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.7291088E-006$   
 $\mu_u = 8.0265E+008$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00174378$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha (5A.5, \text{TB DY}) = 0.002$

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY:  $\mu_u = 0.01186911$

we ((5.4c), TB DY) =  $\alpha s_e * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$

where  $f = \alpha f_p f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$\alpha s_e ((5.4d), \text{TB DY}) = (\alpha s_{e1} * A_{\text{ext}} + \alpha s_{e2} * A_{\text{int}}) / A_{\text{sec}} = 0.11512199$

$\alpha s_{e1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 71100.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length

equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - \text{AnoConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max2 by a length

equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d)) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 455.1997$

$fy1 = 379.3331$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{min} = lb/ld = 0.30798991$

$su1 = 0.4 * esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 379.3331$

with  $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 449.345$

$fy2 = 374.4542$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{min} = lb/lb_{min} = 0.30798991$

$su_2 = 0.4 \cdot esu_{2\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2\_nominal} = 0.08$ ,  
 For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 374.4542$   
 with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 0.30798991$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.08977028$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.0456314$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.08124101$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.11029209$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05606291$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2110448$

$\mu_u = MR_c (4.14) = 8.0265E+008$

$u = su (4.1) = 9.7291088E-006$

-----  
 Calculation of ratio  $lb/ld$

-----  
 Lap Length:  $lb/ld = 0.30798991$

$lb = 300.00$

$ld = 974.0579$

Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} <= 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$

where  $A_{tr\_x}, A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 510.00$

$n = 24.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 653603.866$

Calculation of Shear Strength at edge 1,  $V_{r1} = 653603.866$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{\text{ColO}}$

$V_{\text{ColO}} = 653603.866$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_{s+} + f * V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 140237.117$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 0.00$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.00$

$s/d = 1.59375$

$V_{s,j2} = 61600.349$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.60$

$s/d = 0.85$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78636.768$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 372533.843$

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,

where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(a, \dots)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L * t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe} ((11-5), \text{ACI } 440) = 259.312$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 838832.606$$

$$b_w = 400.00$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$

$$V_{r2} = V_{CoI} \text{ ((10.3), ASCE 41-17) } = k_{nl} * V_{CoIO}$$

$$V_{CoIO} = 653603.866$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$\mu_u = 11.78144$$

$$V_u = 0.00051441$$

$$d = 0.8 * h = 600.00$$

$$N_u = 16273.616$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 140237.117$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 61600.349$$

$V_{s,j1} = 0.00$  is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 510.00$$

$$V_{s,j1} \text{ is multiplied by } Col,j1 = 0.00$$

$$s/d = 1.59375$$

$V_{s,j2} = 61600.349$  is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 510.00$$

$$V_{s,j2} \text{ is multiplied by } Col,j2 = 0.60$$

$$s/d = 0.85$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 250.00$$

$$V_{s,c1} \text{ is multiplied by } Col,c1 = 0.00$$

$$s/d = 1.5625$$

$V_{s,c2} = 78636.768$  is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 250.00$$

$$V_{s,c2} \text{ is multiplied by } Col,c2 = 1.00$$

$$s/d = 0.56818182$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 372533.843$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } 1 = b_1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440) } = 707.00$$

ffe ((11-5), ACI 440) = 259.312  
Ef = 64828.00  
fe = 0.004, from (11.6a), ACI 440  
with fu = 0.01  
From (11-11), ACI 440: Vs + Vf <= 838832.606  
bw = 400.00

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
Section Type: rcjls

#### Constant Properties

Knowledge Factor,  $\gamma = 0.90$   
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_b = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $bi = 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 56787.791$   
Shear Force,  $V_2 = 5209.785$   
Shear Force,  $V_3 = -97.60185$   
Axial Force,  $F = -16800.923$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{st,ten} = 1137.257$

-Compression:  $A_{sc,com} = 2208.54$

-Middle:  $A_{st,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{st,ten,jacket} = 829.3805$

-Compression:  $A_{sc,com,jacket} = 1746.726$

-Middle:  $A_{st,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{st,ten,core} = 307.8761$

-Compression:  $A_{sc,com,core} = 461.8141$

-Middle:  $A_{st,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement,  $DbL = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = \frac{1}{2} u = 0.00025576$

$u = y + p = 0.00028418$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00028418$  ((4.29), Biskinis Phd))

$M_y = 4.1179E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 16800.923$

$E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 3.0742160E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 350.6021$

$d = 707.00$

$y = 0.19345095$

$A = 0.01018613$

$B = 0.00449653$

with  $p_t = 0.00376294$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 16800.923$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6463045E-005$

with  $f_c' * (12.3, (ACI 440)) = 33.48734$

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$   
 $rc = 40.00$   
 $A_e/A_c = 0.31291181$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(\theta_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $\gamma = 0.19180888$   
 $A = 0.01002479$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $\gamma = 0.19276987 < t/d$

#### Calculation of ratio $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.38498739$   
 $l_b = 300.00$   
 $l_d = 779.2463$   
 Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 524.4464$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \max(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$

#### - Calculation of $p$ -

From table 10-8:  $p = 0.00$

with:

- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$

shear control ratio  $V_y E / V_{col} E = 0.81868759$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00376294$

jacket:  $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.000721$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 510.00$

core:  $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00067082$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$  is implemented to account for FRP contribution

where  $f = 2 \cdot t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation  $f_s$  of jacket is used.

$NUD = 16800.923$

$A_g = 440000.00$

$f'_c E = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / section\_area = 27.68182$

$f_{yI} E = (f_{y,ext\_Long\_Reinf} \cdot Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 529.9972$

$f_{yT} E = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 502.0032$

$p_l = Area_{Tot\_Long\_Rein} / (b \cdot d) = 0.01009575$

$b = 750.00$

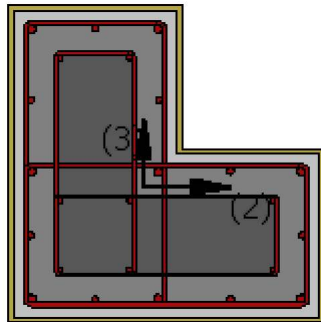
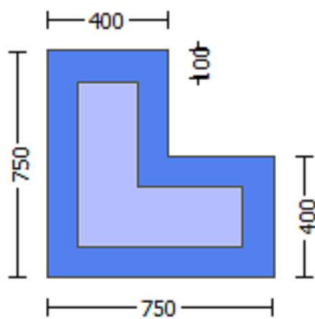


d = 707.00  
f<sub>cE</sub> = 27.68182

-----  
End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
-----

## Calculation No. 9

column C1, Floor 1  
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)  
Analysis: Uniform +X  
Check: Shear capacity VR<sub>d</sub>  
Edge: Start  
Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1  
At local axis: 2  
Integration Section: (a)  
Section Type: rcjcs

Constant Properties

-----  
Knowledge Factor,  $\gamma = 0.90$   
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.  
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$

```

Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$ 
Concrete Elasticity,  $E_c = 21019.039$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material: Steel Strength,  $f_s = f_{sm} = 555.56$ 
Existing Column
Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$ 
Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$ 
#####
Max Height,  $H_{max} = 750.00$ 
Min Height,  $H_{min} = 400.00$ 
Max Width,  $W_{max} = 750.00$ 
Min Width,  $W_{min} = 400.00$ 
Jacket Thickness,  $t_j = 100.00$ 
Cover Thickness,  $c = 25.00$ 
Element Length,  $L = 3000.00$ 
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length  $l_o = l_b = 300.00$ 
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $NoDir = 1$ 
Fiber orientations,  $bi: 0.00^\circ$ 
Number of layers,  $NL = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
EDGE -A-
Bending Moment,  $M_a = -2.3777E+007$ 
Shear Force,  $V_a = -7895.088$ 
EDGE -B-
Bending Moment,  $M_b = 86052.109$ 
Shear Force,  $V_b = 7895.088$ 
BOTH EDGES
Axial Force,  $F = -17072.715$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $As_t = 0.00$ 
-Compression:  $As_c = 5353.274$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $As_{t,ten} = 1137.257$ 
-Compression:  $As_{l,com} = 2208.54$ 
-Middle:  $As_{l,mid} = 2007.478$ 
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$ 
-----
-----

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity  $V_R = *V_n = 558299.293$ 
 $V_n$  ((10.3), ASCE 41-17) =  $k_n * V_{CoI} = 620332.548$ 
 $V_{CoI} = 620332.548$ 
 $k_n = 1.00$ 
displacement_ductility_demand = 0.03382628

```

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_{s+} + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 21.31818$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 2.3777 \times 10^7$

$V_u = 7895.088$

$d = 0.8 \cdot h = 600.00$

$N_u = 17072.715$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 126213.67$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 55439.87$

$V_{s,j1} = 0.00$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.00$

$s/d = 1.59375$

$V_{s,j2} = 55439.87$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.60$

$s/d = 0.85$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 70773.799$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 70773.799$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 1.00$

$s/d = 0.56818182$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 736127.561$

$b_w = 400.00$

displacement\_ductility\_demand is calculated as  $\Delta / y$

- Calculation of  $\phi_y$  for END A -  
for rotation axis 3 and integ. section (a)

From analysis, chord rotation  $\theta = 9.6518553E-005$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00285336$  ((4.29), Biskinis Phd))  
 $M_y = 4.1188E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3011.649  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 1.4491E+014$   
 $factor = 0.30$   
 $A_g = 440000.00$   
Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$   
 $N = 17072.715$   
 $E_c \cdot I_g = E_{c,jacket} \cdot I_{g,jacket} + E_{c,core} \cdot I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\phi_y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:  
flange width,  $b = 750.00$   
web width,  $b_w = 400.00$   
flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 3.0743398E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 350.6021$   
 $d = 707.00$   
 $y = 0.19348343$   
 $A = 0.01018759$   
 $B = 0.004498$   
with  $p_t = 0.00214476$   
 $p_c = 0.00416509$   
 $p_v = 0.00378591$   
 $N = 17072.715$   
 $b = 750.00$   
 $\rho = 0.06082037$   
 $y_{comp} = 1.6462519E-005$   
with  $f_c' (12.3, (ACI 440)) = 33.48734$   
 $f_c = 33.00$   
 $f_l = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $r_c = 40.00$   
 $A_e / A_c = 0.31291181$   
Effective FRP thickness,  $t_f = N L \cdot t \cdot \cos(b_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.19181501$   
 $A = 0.01002364$   
 $B = 0.00440616$   
with  $E_s = 200000.00$   
CONFIRMATION:  $y = 0.19279145 < t/d$

Calculation of ratio  $I_b / I_d$

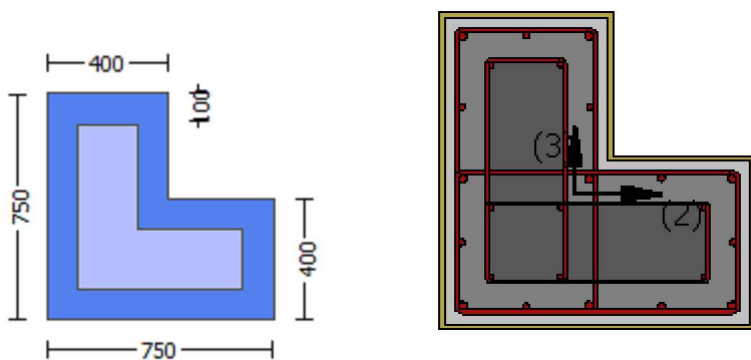
Lap Length:  $I_d / I_{d,min} = 0.38498739$   
 $I_b = 300.00$   
 $I_d = 779.2463$   
Calculation of  $I$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1  
 db = 16.66667  
 Mean strength value of all re-bars:  $f_y = 524.4464$   
 Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1  
 At local axis: 2  
 Integration Section: (a)

## Calculation No. 10

column C1, Floor 1  
 Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)  
 Analysis: Uniform +X  
 Check: Chord rotation capacity (  $\phi$  )  
 Edge: Start  
 Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At Shear local axis: 3  
 (Bending local axis: 2)  
 Section Type: rcjls

Constant Properties

Knowledge Factor,  $\phi = 0.90$   
 Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,  
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.03889

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

-----

#### Stepwise Properties

-----

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -0.00051441$

EDGE -B-

Shear Force,  $V_b = 0.00051441$

BOTH EDGES

Axial Force,  $F = -16273.616$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1137.257$

-Compression:  $As_{l,com} = 2208.54$

-Middle:  $As_{l,mid} = 2007.478$

-----

-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.81868759$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$   
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 8.0265E+008$

$\mu_{1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 8.0265E+008$

$\mu_{2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

-----  
Calculation of  $\mu_{1+}$   
-----

-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 8.9479397E-006$

$M_u = 4.8921E+008$   
-----

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

$\alpha_0$  (5A.5, TBDY) = 0.002

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_c = 0.01186911$

$\mu_{cc}$  ((5.4c), TBDY) =  $\alpha_{se} * \mu_{sh, \min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$

where  $f = \alpha_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$   
-----

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$   
-----

$R = 40.00$

Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{f} = 0.015$

$\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{conf, \max 1} - A_{noConf1})/A_{conf, \max 1}) * (A_{conf, \min 1}/A_{conf, \max 1}), 0) = 0.11081094$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 0.87336895$

Expression (5.4d) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 0.87336895$   
 $p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 0.87336895$   
 $p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 440000.00$   
 $s_1 = 510.00$   
 $s_2 = 250.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$   
 $c$  = confinement factor = 1.03889

$y_1 = 0.0014252$   
 $sh_1 = 0.00456062$   
 $ft_1 = 449.345$   
 $fy_1 = 374.4542$   
 $su_1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $su_1 = 0.4 * esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 374.4542$

with  $Es_1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.0014252$   
 $sh_2 = 0.00456062$   
 $ft_2 = 455.1997$



```

fy2 = 379.3331
su2 = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.30798991
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 379.3331
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0014252
shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.30798991
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322

```

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

```

--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.30798991
lb = 300.00
ld = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00

```

$cb = 25.00$   
 $Ktr = 0.8418647$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

Calculation of  $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.7291088E-006$   
 $\mu_u = 8.0265E+008$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00174378$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha (5A.5, \text{TB DY}) = 0.002$

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY:  $\mu_u = 0.01186911$

we ((5.4c), TB DY) =  $\alpha s_e * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$

where  $f = \alpha f_p f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TB DY) is modified as  $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = NL * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$\alpha s_e ((5.4d), \text{TB DY}) = (\alpha s_{e1} * A_{\text{ext}} + \alpha s_{e2} * A_{\text{int}}) / A_{\text{sec}} = 0.11512199$

$\alpha s_{e1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 71100.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length

equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - \text{AnoConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max2 by a length

equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d)) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 455.1997$

$fy1 = 379.3331$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{min} = lb/ld = 0.30798991$

$su1 = 0.4 * esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 379.3331$

with  $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 449.345$

$fy2 = 374.4542$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{min} = lb/lb_{min} = 0.30798991$

$su_2 = 0.4 \cdot esu_{2\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2\_nominal} = 0.08$ ,  
 For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 374.4542$   
 with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 0.30798991$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.08977028$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.0456314$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.08124101$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.11029209$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05606291$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2110448$

$\mu_u = MR_c (4.14) = 8.0265E+008$

$u = su (4.1) = 9.7291088E-006$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.30798991$

$lb = 300.00$

$ld = 974.0579$

Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} <= 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$

where  $A_{tr\_x}, A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 510.00$

$n = 24.00$

## Calculation of $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.9479397\text{E-}006$$

$$\mu_{2+} = 4.8921\text{E+}008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha_{cc} \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_{2+}: \mu_{2+} = \text{shear\_factor} * \text{Max}(\mu_{2+}, \alpha_{cc}) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{2+} = 0.01186911$$

$$\mu_{2+} \text{ ((5.4c), TBDY)} = \alpha_{se} * \mu_{2+,min} * f_{y,we} / f_{ce} + \text{Min}(\mu_{2+}, \mu_{2+,min}) = 0.04377629$$

where  $\mu_{2+,min} = \alpha_f * \mu_{2+,min} * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{2+,min} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{2+,min} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\mu_{2+,min} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{2+,min} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{2+,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY)} = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf1}$ ,  $A_{conf,min1}$  and  $A_{conf,max1}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (\geq \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $ps2$  (5.4d) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $ps2$  ((5.4d), TBDY) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 449.345$

$fy1 = 374.4542$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30798991$

$su1 = 0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} \cdot A_{sl,ten,jacket} + f_{s,core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 374.4542$

with  $Es1 = (E_{s,jacket} \cdot A_{sl,ten,jacket} + E_{s,core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 455.1997$

$fy2 = 379.3331$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$

$su2 = 0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y2, sh2, ft2, fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (f_{s,jacket} \cdot A_{sl,com,jacket} + f_{s,core} \cdot A_{sl,com,core}) / A_{sl,com} = 379.3331$

```

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0014252
shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.30798991
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.30798991
lb = 300.00
ld = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 0.8418647
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 510.00
n = 24.00
-----
-----
-----
Calculation of Mu2-
-----

```

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 9.7291088E-006$$

$$Mu = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\phi_0 (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_0) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01186911$$

$$\phi_{we} (5.4c, \text{TBDY}) = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.04377629$$

where  $\phi_{fx} = a_f * \phi_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\phi_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} (5.4d, \text{TBDY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$a_{se1} = \text{Max}(((A_{\text{conf}, \max 1} - A_{\text{noConf1}}) / A_{\text{conf}, \max 1}) * (A_{\text{conf}, \min 1} / A_{\text{conf}, \max 1}), 0) = 0.11081094$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf}, \min}$  and  $A_{\text{conf}, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf}, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf}, \min 1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf}, \max 1}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf}, \max 2} - A_{\text{noConf2}}) / A_{\text{conf}, \max 2}) * (A_{\text{conf}, \min 2} / A_{\text{conf}, \max 2}), 0) = 0.12134906$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf}, \min}$  and  $A_{\text{conf}, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf}, \max 2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{\text{conf}, \min 2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf}, \max 2}$  by a length



equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} \cdot Fywe = \min(psh_x \cdot Fywe, psh_y \cdot Fywe) = 0.87336895$

Expression (5.4d) for  $psh_{min} \cdot Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.000721$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

$psh_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.000721$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 455.1997

fy1 = 379.3331

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.30798991

su1 =  $0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 379.3331$

with Es1 =  $(Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$

y2 = 0.0014252

sh2 = 0.00456062

ft2 = 449.345

fy2 = 374.4542

su2 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30798991

su2 =  $0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 =  $(fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 374.4542$

with Es2 =  $(Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

yv = 0.0014252

shv = 0.00456062

ftv = 453.2097

fyv = 377.6747

suv = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $y_v$ ,  $shv$ ,  $ftv$ ,  $fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs\_jacket * Asl\_mid\_jacket + fs\_mid * Asl\_mid\_core) / Asl\_mid = 377.6747$   
with  $Esv = (Es\_jacket * Asl\_mid\_jacket + Es\_mid * Asl\_mid\_core) / Asl\_mid = 200000.00$   
 $1 = Asl\_ten / (b * d) * (fs_1 / fc) = 0.08977028$   
 $2 = Asl\_com / (b * d) * (fs_2 / fc) = 0.0456314$   
 $v = Asl\_mid / (b * d) * (fsv / fc) = 0.08124101$   
and confined core properties:  
 $b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl\_ten / (b * d) * (fs_1 / fc) = 0.11029209$   
 $2 = Asl\_com / (b * d) * (fs_2 / fc) = 0.05606291$   
 $v = Asl\_mid / (b * d) * (fsv / fc) = 0.099813$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)  
--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.2110448$   
 $Mu = MRc (4.14) = 8.0265E+008$   
 $u = su (4.1) = 9.7291088E-006$

---

Calculation of ratio  $l_b/l_d$

---

Lap Length:  $l_b/l_d = 0.30798991$   
 $l_b = 300.00$   
 $l_d = 974.0579$   
Calculation of  $l_b,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $fy = 655.558$   
Mean concrete strength:  $fc' = (fc'_jacket * Area\_jacket + fc'_core * Area\_core) / Area\_section = 27.68182$ , but  $fc'^{0.5} <=$   
8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 0.8418647$   
 $Atr = \text{Min}(Atr\_x, Atr\_y) = 257.6106$   
where  $Atr\_x$ ,  $Atr\_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s\_external, s\_internal) = 510.00$   
 $n = 24.00$

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Calculation of Shear Strength  $Vr = \text{Min}(Vr1, Vr2) = 653603.866$

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Calculation of Shear Strength at edge 1,  $Vr1 = 653603.866$   
 $Vr1 = VCol ((10.3), ASCE 41-17) = knl * VColO$   
 $VColO = 653603.866$   
 $knl = 1$  (zero step-static loading)

---

NOTE: In expression (10-3) ' $V_s = A_v * fy * d / s$ ' is replaced by ' $V_s + f * V_f$ '

where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77537$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 140237.117$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 61600.349$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $Col,j1 = 0.60$

$s/d = 0.85$

$V_{s,j2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $Col,j2 = 0.00$

$s/d = 1.59375$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 78636.768$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$

$s/d = 1.5625$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,

where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$

$b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Col0}$

$V_{Col0} = 653603.866$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_c \cdot \text{Area}_{\text{jacket}} + f'_c \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77482$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 140237.117$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 61600.349$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.60$

$s/d = 0.85$

$V_{s,j2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.00$

$s/d = 1.59375$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 78636.768$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 0.00$

$s/d = 1.5625$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,

where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$

$b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At local axis: 3

```

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcjls

Constant Properties
-----
Knowledge Factor,   = 0.90
Mean strength values are used for both shear and moment calculations.
Consequently:
Jacket
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$ 
Concrete Elasticity,  $E_c = 26999.444$ 
Steel Elasticity,  $E_s = 200000.00$ 
Existing Column
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$ 
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$ 
Concrete Elasticity,  $E_c = 21019.039$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Jacket
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$ 
Existing Column
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$ 
#####
Max Height,  $H_{max} = 750.00$ 
Min Height,  $H_{min} = 400.00$ 
Max Width,  $W_{max} = 750.00$ 
Min Width,  $W_{min} = 400.00$ 
Jacket Thickness,  $t_j = 100.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.03889
Element Length,  $L = 3000.00$ 
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length  $l_o = 300.00$ 
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $\epsilon_{fu} = 0.01$ 
Number of directions,  $N_{oDir} = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $N_L = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
At local axis: 2
EDGE -A-
Shear Force,  $V_a = -0.00051441$ 
EDGE -B-
Shear Force,  $V_b = 0.00051441$ 
BOTH EDGES
Axial Force,  $F = -16273.616$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)

```

-Tension:  $As_t = 0.00$   
 -Compression:  $As_c = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{t,ten} = 1137.257$   
 -Compression:  $As_{c,com} = 2208.54$   
 -Middle:  $As_{mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.81868759$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$   
 with  
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 8.0265E+008$   
 $Mu_{1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $Mu_{1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 8.0265E+008$   
 $Mu_{2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination  
 $Mu_{2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $Mu_{1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 8.9479397E-006$   
 $M_u = 4.8921E+008$

with full section properties:

$b = 750.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093001$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\phi_{co} \text{ (5A.5, TBDY)} = 0.002$

Final value of  $\phi_u$ :  $\phi_u = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_{cu} = 0.01186911$

$\phi_{ve} \text{ ((5.4c), TBDY)} = \phi_{se} * \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.04377629$

where  $\phi_{fx} = \phi_{af} * \phi_{pf} * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\phi_{af} = 1 - (\text{Unconfined area})/(\text{total area})$

$\phi_{af} = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$\phi_{fy} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\phi_{af} = 1 - (\text{Unconfined area})/(\text{total area})$

$\phi_{af} = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_f = 0.015$   
 $ase((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.11512199$   
 $ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 0.87336895$   
 Expression (5.4d) for  $psh_{min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

---

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2(5.4d) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

---

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2((5.4d), TBDY) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

---

$A_{sec} = 440000.00$   
 $s1 = 510.00$   
 $s2 = 250.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$   
 $c$  = confinement factor = 1.03889  
 $y1 = 0.0014252$   
 $sh1 = 0.00456062$   
 $ft1 = 449.345$   
 $fy1 = 374.4542$   
 $su1 = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

```

lo/lou,min = lb/ld = 0.30798991
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 374.4542
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0014252
sh2 = 0.00456062
ft2 = 455.1997
fy2 = 379.3331
su2 = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.30798991
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 379.3331
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0014252
shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.30798991
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006

```

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.30798991



$l_b = 300.00$   
 $l_d = 974.0579$   
 Calculation of  $l_b$ , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \max(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$

Calculation of  $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$u = 9.7291088E-006$   
 $\mu = 8.0265E+008$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00174378$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha_1 (5A.5, TBDY) = 0.002$   
 Final value of  $\mu$ :  $\mu^* = shear\_factor \cdot \max(\mu, \mu_c) = 0.01186911$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\mu = 0.01186911$   
 $\mu_e ((5.4c), TBDY) = \alpha_1 \cdot \mu_{min} \cdot f_{ywe} / f_{ce} + \min(f_x, f_y) = 0.04377629$   
 where  $f = \alpha_1 \cdot \mu_{min} \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (Unconfined\ area) / (total\ area)$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $\mu_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (Unconfined\ area) / (total\ area)$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $\mu_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = N L^* t \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$$ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.11512199$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$$psh2((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$$psh2((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$$A_{sec} = 440000.00$$

$$s1 = 510.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0014252$$

$$sh1 = 0.00456062$$

$$ft1 = 455.1997$$

$$fy1 = 379.3331$$

$$su1 = 0.00542681$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30798991$$

$$su1 = 0.4 * esu1_{nominal}((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

```

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 379.3331
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0014252
sh2 = 0.00456062
ft2 = 449.345
fy2 = 374.4542
su2 = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.30798991
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 374.4542
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0014252
shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.30798991
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.08977028
2 = Asl,com/(b*d)*(fs2/fc) = 0.0456314
v = Asl,mid/(b*d)*(fsv/fc) = 0.08124101
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11029209
2 = Asl,com/(b*d)*(fs2/fc) = 0.05606291
v = Asl,mid/(b*d)*(fsv/fc) = 0.099813
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.2110448
Mu = MRc (4.14) = 8.0265E+008
u = su (4.1) = 9.7291088E-006

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.30798991
lb = 300.00
lb = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558

```

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 0.8418647$$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$$s = \max(s_{external}, s_{internal}) = 510.00$$

$$n = 24.00$$

Calculation of  $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.9479397E-006$$

$$\mu_{2+} = 4.8921E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$fc = 33.00$$

$$cc(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} \cdot \max(\mu, cc) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01186911$$

$$\mu_{e((5.4c), TBDY)} = a_{se} \cdot \mu_{min} \cdot f_{ywe} / f_{ce} + \min(f_x, f_y) = 0.04377629$$

where  $f = a_f \cdot p_f \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L \cdot t \cdot \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

$$a_{se}((5.4d), TBDY) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int}) / A_{sec} = 0.11512199$$

$$a_{se1} = \max(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 71100.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 0.87336895$

Expression (5.4d) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 449.345

fy1 = 374.4542

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lo,min = lb/ld = 0.30798991

su1 =  $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,\text{jacket}} * A_{s,\text{ten,jacket}} + f_{s,\text{core}} * A_{s,\text{ten,core}}) / A_{s,\text{ten}} = 374.4542$

with Es1 =  $(E_{s,\text{jacket}} * A_{s,\text{ten,jacket}} + E_{s,\text{core}} * A_{s,\text{ten,core}}) / A_{s,\text{ten}} = 200000.00$

y2 = 0.0014252

sh2 = 0.00456062

ft2 = 455.1997

fy2 = 379.3331

```

su2 = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.30798991
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 379.3331
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0014252
shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.30798991
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854

```

and confined core properties:

```

b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322

```

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

```

---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.30798991
lb = 300.00
lb = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00

```

$$K_{tr} = 0.8418647$$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \max(s_{external}, s_{internal}) = 510.00$$

$$n = 24.00$$

Calculation of  $\mu_2$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.7291088E-006$$

$$\mu_2 = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha_2(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear\_factor} * \max(\mu_2, \alpha_2) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_2 = 0.01186911$$

$$\text{we ((5.4c), TBDY) } = \alpha_2 * \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.04377629$$

where  $f_x = \alpha_f * \rho_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$\alpha_{se}((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$\alpha_{se1} = \max((A_{conf,max1} - A_{noConf1}) / A_{conf,max1} * (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-AnoConf2)/A_{conf,max2})*(A_{conf,min2}/A_{conf,max2}),0) = 0.12134906$   
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.  
AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 0.87336895$   
Expression (5.4d) for  $psh,min*Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh,x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 0.87336895$   
 $psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.000721$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d)) = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548  
-----

-----  
 $psh,y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 0.87336895$   
 $psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.000721$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548  
-----

-----  
Asec = 440000.00  
s1 = 510.00  
s2 = 250.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00  
From ((5.A5), TBDY), TBDY: cc = 0.00238888  
c = confinement factor = 1.03889  
y1 = 0.0014252  
sh1 = 0.00456062  
ft1 = 455.1997  
fy1 = 379.3331  
su1 = 0.00542681  
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
lo/lou,min = lb/l\_d = 0.30798991  
su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032  
From table 5A.1, TBDY: esu1\_nominal = 0.08,  
For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.  
y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with fs1 = (fs,jacket\*Asl,tens,jacket + fs,core\*Asl,tens,core)/Asl,tens = 379.3331  
with Es1 = (Es,jacket\*Asl,tens,jacket + Es,core\*Asl,tens,core)/Asl,tens = 200000.00  
y2 = 0.0014252  
sh2 = 0.00456062  
ft2 = 449.345  
fy2 = 374.4542  
su2 = 0.00542681  
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
lo/lou,min = lb/lb,min = 0.30798991  
su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032  
-----



From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs2 = (fs\_jacket \cdot Asl\_com\_jacket + fs\_core \cdot Asl\_com\_core) / Asl\_com = 374.4542$   
with  $Es2 = (Es\_jacket \cdot Asl\_com\_jacket + Es\_core \cdot Asl\_com\_core) / Asl\_com = 200000.00$   
 $yv = 0.0014252$   
 $shv = 0.00456062$   
 $ftv = 453.2097$   
 $fyv = 377.6747$   
 $suv = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lo_{u,min} = lb/ld = 0.30798991$   
 $suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs\_jacket \cdot Asl\_mid\_jacket + fs\_mid \cdot Asl\_mid\_core) / Asl\_mid = 377.6747$   
with  $Es_v = (Es\_jacket \cdot Asl\_mid\_jacket + Es\_mid \cdot Asl\_mid\_core) / Asl\_mid = 200000.00$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.08977028$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.0456314$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.08124101$   
and confined core properties:  
 $b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.11029209$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.05606291$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.099813$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)  
--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.2110448$   
 $Mu = MRc (4.14) = 8.0265E+008$   
 $u = su (4.1) = 9.7291088E-006$   
-----  
Calculation of ratio  $lb/ld$   
-----  
Lap Length:  $lb/ld = 0.30798991$   
 $lb = 300.00$   
 $ld = 974.0579$   
Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $fy = 655.558$   
Mean concrete strength:  $fc' = (fc'_jacket \cdot Area\_jacket + fc'_core \cdot Area\_core) / Area\_section = 27.68182$ , but  $fc'^{0.5} < =$   
8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 0.8418647$   
 $Atr = Min(Atr\_x, Atr\_y) = 257.6106$   
where  $Atr\_x, Atr\_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = Max(s\_external, s\_internal) = 510.00$   
 $n = 24.00$   
-----

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 653603.866$

Calculation of Shear Strength at edge 1,  $V_{r1} = 653603.866$

$V_{r1} = V_{Col} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 653603.866$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 140237.117$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 0.00$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.00$

$s/d = 1.59375$

$V_{s,j2} = 61600.349$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.60$

$s/d = 0.85$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78636.768$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 372533.843$

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L * t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe} ((11-5), \text{ACI } 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$   
 $bw = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 653603.866$   
 $knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 11.78144$   
 $V_u = 0.00051441$   
 $d = 0.8 * h = 600.00$   
 $N_u = 16273.616$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 140237.117$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 61600.349$   
 $V_{sj1} = 0.00$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 0.00$   
 $s/d = 1.59375$   
 $V_{sj2} = 61600.349$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 0.60$   
 $s/d = 0.85$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 78636.768$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL * t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$

Ef = 64828.00  
fe = 0.004, from (11.6a), ACI 440  
with fu = 0.01  
From (11-11), ACI 440: Vs + Vf <= 838832.606  
bw = 400.00

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
At local axis: 2  
Integration Section: (a)  
Section Type: rcjls

#### Constant Properties

Knowledge Factor,  $\gamma = 0.90$   
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_b = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -303215.468$   
Shear Force,  $V_2 = -7895.088$   
Shear Force,  $V_3 = 147.9095$   
Axial Force,  $F = -17072.715$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$   
 -Compression:  $As_{lc} = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten} = 1137.257$   
 -Compression:  $As_{l,com} = 2208.54$   
 -Middle:  $As_{l,mid} = 2007.478$   
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten,jacket} = 829.3805$   
 -Compression:  $As_{l,com,jacket} = 1746.726$   
 -Middle:  $As_{l,mid,jacket} = 1545.664$   
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten,core} = 307.8761$   
 -Compression:  $As_{l,com,core} = 461.8141$   
 -Middle:  $As_{l,mid,core} = 461.8141$   
 Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = \phi \cdot u = 0.03240089$   
 $u = y + p = 0.03600099$

- Calculation of  $y$  -

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00194226$  ((4.29), Biskinis Phd))  
 $M_y = 4.1188E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 2050.007  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 1.4491E+014$   
 $factor = 0.30$   
 $A_g = 440000.00$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$   
 $N = 17072.715$   
 $E_c \cdot I_g = E_{c,jacket} \cdot I_{g,jacket} + E_{c,core} \cdot I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:  
 flange width,  $b = 750.00$   
 web width,  $b_w = 400.00$   
 flange thickness,  $t = 400.00$

$y = \min(y_{ten}, y_{com})$   
 $y_{ten} = 3.0743398E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \min(f_y, 1.25 \cdot f_y \cdot (I_b/I_d)^{2/3}) = 350.6021$   
 $d = 707.00$   
 $y = 0.19348343$   
 $A = 0.01018759$   
 $B = 0.004498$   
 with  $p_t = 0.00376294$   
 $p_c = 0.00416509$   
 $p_v = 0.00378591$   
 $N = 17072.715$   
 $b = 750.00$   
 $\rho = 0.06082037$   
 $y_{comp} = 1.6462519E-005$   
 with  $f'_c$  (12.3, (ACI 440)) = 33.48734  
 $f_c = 33.00$   
 $f_l = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$

$rc = 40.00$   
 $Ae/Ac = 0.31291181$   
 Effective FRP thickness,  $tf = NL * t * \cos(b1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.19181501$   
 $A = 0.01002364$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.19279145 < t/d$

#### Calculation of ratio $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.38498739$   
 $l_b = 300.00$   
 $l_d = 779.2463$   
 Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 524.4464$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.68182$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \max(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$

#### - Calculation of $p$ -

From table 10-8:  $p = 0.03405873$

with:

- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$

shear control ratio  $V_y E / V_{ColOE} = 0.81868759$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 * tf / bw * (f_{fe} / f_s) = 0.00376294$

jacket:  $s_1 = A_{v1} * L_{stir1} / (s_1 * A_g) = 0.000721$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 510.00$

core:  $s_2 = A_{v2} * L_{stir2} / (s_2 * A_g) = 0.00067082$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2 * tf / bw * (f_{fe} / f_s)$  is implemented to account for FRP contribution

where  $f = 2 * tf / bw$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation  $f_s$  of jacket is used.

$NUD = 17072.715$

$A_g = 440000.00$

$f_{cE} = (f_{c,jacket} * Area_{jacket} + f_{c,core} * Area_{core}) / section\_area = 27.68182$

$f_{yIE} = (f_{y,ext\_Long\_Reinf} * Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} * Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 529.9972$

$f_{yIE} = (f_{y,ext\_Trans\_Reinf} * s_1 + f_{y,int\_Trans\_Reinf} * s_2) / (s_1 + s_2) = 502.0032$

$p_l = Area_{Tot\_Long\_Rein} / (b * d) = 0.01009575$

$b = 750.00$

$d = 707.00$

$$f_{cE} = 27.68182$$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 11

column C1, Floor 1

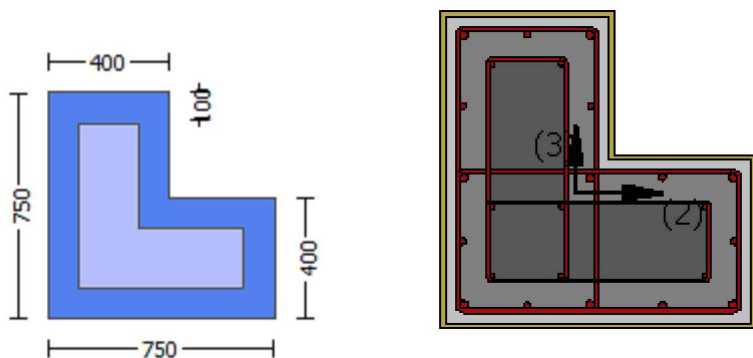
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $VR_d$

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 0.90$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$

```

Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, fc = fcm = 33.00
New material: Steel Strength, fs = fsm = 555.56
Existing Column
Existing material: Concrete Strength, fc = fcm = 20.00
Existing material: Steel Strength, fs = fsm = 444.44
#####
Max Height, Hmax = 750.00
Min Height, Hmin = 400.00
Max Width, Wmax = 750.00
Min Width, Wmin = 400.00
Jacket Thickness, tj = 100.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length lo = lb = 300.00
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, ffu = 1055.00
Tensile Modulus, Ef = 64828.00
Elongation, efu = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

Stepwise Properties
-----
EDGE -A-
Bending Moment, Ma = -303215.468
Shear Force, Va = 147.9095
EDGE -B-
Bending Moment, Mb = -138295.202
Shear Force, Vb = -147.9095
BOTH EDGES
Axial Force, F = -17072.715
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 5353.274
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1137.257
-Compression: Asl,com = 2208.54
-Middle: Asl,mid = 2007.478
Mean Diameter of Tension Reinforcement, DbL,ten = 16.80
-----
-----

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity VR =  $\phi V_n$  = 579843.527
Vn ((10.3), ASCE 41-17) = knl*VColO = 644270.586
VCol = 644270.586
knl = 1.00
displacement_ductility_demand = 0.01946439
-----

```



NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_c \text{ jacket} \cdot \text{Area}_{\text{jacket}} + f'_c \text{ core} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 21.31818$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 3.41668$

$\mu_u = 303215.468$

$V_u = 147.9095$

$d = 0.8 \cdot h = 600.00$

$N_u = 17072.715$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 126213.67$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 55439.87$

$V_{s,j1} = 55439.87$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.60$

$s/d = 0.85$

$V_{s,j2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.00$

$s/d = 1.59375$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 70773.799$

$V_{s,c1} = 70773.799$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $\text{Col},c2 = 0.00$

$s/d = 1.5625$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,

where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 736127.561$

$b_w = 400.00$

displacement\_ductility\_demand is calculated as  $\Delta / y$

- Calculation of  $\Delta / y$  for END A -

for rotation axis 2 and integ. section (a)

From analysis, chord rotation =  $3.7804926E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.00194226$  ((4.29), Biskinis Phd))

$M_y = 4.1188E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 2050.007

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 17072.715$

$E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange (  $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 3.0743398E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 350.6021$

$d = 707.00$

$y = 0.19348343$

$A = 0.01018759$

$B = 0.004498$

with  $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 17072.715$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6462519E-005$

with  $f_c' (12.3, (ACI 440)) = 33.48734$

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e / A_c = 0.31291181$

Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$

effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19181501$

$A = 0.01002364$

$B = 0.00440616$

with  $E_s = 200000.00$

CONFIRMATION:  $y = 0.19279145 < t/d$

Calculation of ratio  $I_b / I_d$

Lap Length:  $I_d / I_{d,min} = 0.38498739$

$I_b = 300.00$

$I_d = 779.2463$

Calculation of  $I$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 524.4464$   
 Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 12

column C1, Floor 1

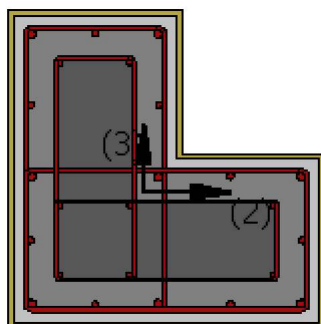
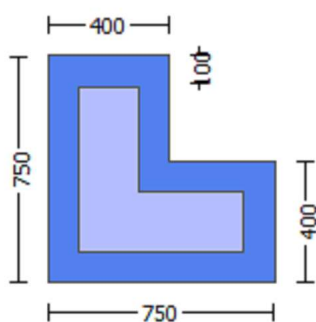
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\mu$  )

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlc

Constant Properties

Knowledge Factor,  $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Jacket  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.03889  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $ef_u = 0.01$   
 Number of directions,  $NoDir = 1$   
 Fiber orientations,  $bi: 0.00^\circ$   
 Number of layers,  $NL = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 3  
 EDGE -A-  
 Shear Force,  $V_a = -0.00051441$   
 EDGE -B-  
 Shear Force,  $V_b = 0.00051441$   
 BOTH EDGES  
 Axial Force,  $F = -16273.616$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $As_t = 0.00$   
 -Compression:  $As_c = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{t,ten} = 1137.257$   
 -Compression:  $As_{l,com} = 2208.54$   
 -Middle:  $As_{l,mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.81868759$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$   
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.0265E+008$

$M_{u1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.0265E+008$

$M_{u2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

-----  
Calculation of  $M_{u1+}$   
-----

-----  
Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 8.9479397E-006$

$M_u = 4.8921E+008$   
-----

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

$\phi_c$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01186911$

$\phi_{ue}$  ((5.4c), TBDY) =  $a_{se} * \phi_{u,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.04377629$

where  $\phi = a_f * \phi_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $\phi_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$   
-----

$\phi_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$   
-----

$R = 40.00$

Effective FRP thickness,  $t_f = N_L * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,e} = 0.015$

$a_{se}$  ((5.4d), TBDY) =  $(a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.11512199$

$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.11081094$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 71100.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 0.87336895$

Expression (5.4d) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 449.345

fy1 = 374.4542

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lo,min = lb/ld = 0.30798991

su1 =  $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,\text{jacket}} * A_{s,\text{ten,jacket}} + f_{s,\text{core}} * A_{s,\text{ten,core}}) / A_{s,\text{ten}} = 374.4542$

with Es1 =  $(E_{s,\text{jacket}} * A_{s,\text{ten,jacket}} + E_{s,\text{core}} * A_{s,\text{ten,core}}) / A_{s,\text{ten}} = 200000.00$

y2 = 0.0014252

sh2 = 0.00456062

ft2 = 455.1997

fy2 = 379.3331

```

su2 = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.30798991
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 379.3331
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0014252
shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.30798991
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854

```

and confined core properties:

```

b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322

```

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

```

---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.30798991
lb = 300.00
ld = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00

```

$$K_{tr} = 0.8418647$$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \max(s_{external}, s_{internal}) = 510.00$$

$$n = 24.00$$

Calculation of  $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.7291088E-006$$

$$\mu_1 = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha_1(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu_1: \mu_1^* = \text{shear\_factor} * \max(\mu_1, \alpha_1) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \mu_1 = 0.01186911$$

$$\text{we ((5.4c), TB DY) } = \alpha_1 * \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.04377629$$

where  $f_x = \alpha_1 * \rho_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TB DY) is modified as  $\alpha_1 = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_1 = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TB DY) is modified as  $\alpha_1 = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_1 = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$\alpha_{se} ((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.11512199$$

$$\alpha_{se1} = \max(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.



AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-AnoConf2)/A_{conf,max2})*(A_{conf,min2}/A_{conf,max2}),0) = 0.12134906$   
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.  
AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 0.87336895$   
Expression (5.4d) for  $psh,min*Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 0.87336895$   
 $psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.000721$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d)) = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

$psh,y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 0.87336895$   
 $psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.000721$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00  
s1 = 510.00  
s2 = 250.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00  
From ((5.A5), TBDY), TBDY: cc = 0.00238888  
c = confinement factor = 1.03889  
y1 = 0.0014252  
sh1 = 0.00456062  
ft1 = 455.1997  
fy1 = 379.3331  
su1 = 0.00542681  
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
lo/lou,min = lb/ld = 0.30798991  
su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032  
From table 5A.1, TBDY: esu1\_nominal = 0.08,  
For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.  
y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 379.3331  
with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00  
y2 = 0.0014252  
sh2 = 0.00456062  
ft2 = 449.345  
fy2 = 374.4542  
su2 = 0.00542681  
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
lo/lou,min = lb/lb,min = 0.30798991  
su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $es_{u2\_nominal} = 0.08$ ,  
 For calculation of  $es_{u2\_nominal}$  and  $y_2$ ,  $sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fs_{y2} = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} \cdot A_{sl,com,jacket} + fs_{core} \cdot A_{sl,com,core})/A_{sl,com} = 374.4542$   
 with  $Es_2 = (Es_{jacket} \cdot A_{sl,com,jacket} + Es_{core} \cdot A_{sl,com,core})/A_{sl,com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $s_{uv} = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $s_{uv} = 0.4 \cdot es_{uv\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $es_{uv\_nominal} = 0.08$ ,  
 considering characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $es_{uv\_nominal}$  and  $y_v$ ,  $sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} \cdot A_{sl,mid,jacket} + fs_{mid} \cdot A_{sl,mid,core})/A_{sl,mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} \cdot A_{sl,mid,jacket} + Es_{mid} \cdot A_{sl,mid,core})/A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.08977028$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.0456314$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.08124101$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.11029209$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.05606291$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2110448$   
 $\mu_u = MR_c (4.14) = 8.0265E+008$   
 $u = su (4.1) = 9.7291088E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$   
 $l_b = 300.00$   
 $l_d = 974.0579$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$

$db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core})/Area_{section} = 27.68182$ , but  $fc'^{0.5} < =$   
 $8.3 \text{ MPa} (22.5.3.1, ACI 318-14)$   
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
 where  $A_{tr\_x}, A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$

## Calculation of $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.9479397\text{E-}006$$

$$\mu_{2+} = 4.8921\text{E+}008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha_{cc} (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \alpha_{cu}: \alpha_{cu} = \text{shear\_factor} * \text{Max}(\alpha_{cu}, \alpha_{cc}) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \alpha_{cu} = 0.01186911$$

$$\alpha_{we} ((5.4c), \text{TBDY}) = \alpha_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\alpha_{fx}, \alpha_{fy}) = 0.04377629$$

where  $f = \alpha_f * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\alpha_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\alpha_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\alpha_{u,f} = 0.015$$

$$\alpha_{se} ((5.4d), \text{TBDY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (\geq \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 0.87336895$

Expression (5.4d) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 0.87336895$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  (5.4d) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 0.87336895$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 449.345$

$fy1 = 374.4542$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30798991$

$su1 = 0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} \cdot A_{sl,ten,jacket} + f_{s,core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 374.4542$

with  $Es1 = (E_{s,jacket} \cdot A_{sl,ten,jacket} + E_{s,core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 455.1997$

$fy2 = 379.3331$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$

$su2 = 0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y2, sh2, ft2, fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (f_{s,jacket} \cdot A_{sl,com,jacket} + f_{s,core} \cdot A_{sl,com,core}) / A_{sl,com} = 379.3331$

with  $Es2 = (E_{s,jacket} \cdot A_{sl,com,jacket} + E_{s,core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$

```

yv = 0.0014252
shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 0.30798991
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
    2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
    v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
    c = confinement factor = 1.03889
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
    2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
    v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006
-----

Calculation of ratio lb/ld
-----

Lap Length: lb/ld = 0.30798991
lb = 300.00
ld = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 0.8418647
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 510.00
n = 24.00
-----
-----
-----

Calculation of Mu2-
-----
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-----

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Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 9.7291088E-006$$

$$\mu_u = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\phi_{(5A.5, \text{TBDY})} = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01186911$$

$$\phi_{(5.4c, \text{TBDY})} = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.04377629$$

where  $\phi_{fx} = a_f * \phi_{pf} * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\phi_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} ((5.4d), \text{TBDY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.12134906$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max2}} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{\text{conf,min2}} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max2}}$  by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 0.87336895$   
 Expression (5.4d) for  $psh,min*Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 0.87336895$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.000721$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ (5.4d)} = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

-----  
 $psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 0.87336895$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.000721$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

-----  
 $Asec = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$fywe1 = 694.45$

$fywe2 = 555.55$

$fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 455.1997$

$fy1 = 379.3331$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$

$lo/lou,min = lb/ld = 0.30798991$

$su1 = 0.4*esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 379.3331$

with  $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 449.345$

$fy2 = 374.4542$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$

$lo/lou,min = lb/lb,min = 0.30798991$

$su2 = 0.4*esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 374.4542$

with  $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$

$yv = 0.0014252$

$shv = 0.00456062$

$ftv = 453.2097$

$fyv = 377.6747$

$suv = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 377.6747$   
with  $Esv = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.08977028$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.0456314$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.08124101$   
and confined core properties:  
 $b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.11029209$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05606291$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.099813$   
Case/Assumption: Unconfined full section - Steel rupture  
'satisfies Eq. (4.3)  
--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
--->  
 $su (4.9) = 0.2110448$   
 $Mu = MRc (4.14) = 8.0265E+008$   
 $u = su (4.1) = 9.7291088E-006$   
-----  
Calculation of ratio  $l_b/l_d$   
-----  
Lap Length:  $l_b/l_d = 0.30798991$   
 $l_b = 300.00$   
 $l_d = 974.0579$   
Calculation of  $l_b,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
Mean strength value of all re-bars:  $fy = 655.558$   
Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} < =$   
8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 0.8418647$   
 $Atr = Min(Atr_x, Atr_y) = 257.6106$   
where  $Atr_x$ ,  $Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = Max(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$   
-----  
-----  
-----  
Calculation of Shear Strength  $Vr = Min(Vr1, Vr2) = 653603.866$   
-----  
Calculation of Shear Strength at edge 1,  $Vr1 = 653603.866$   
 $Vr1 = VCol ((10.3), ASCE 41-17) = knl * VColO$   
 $VColO = 653603.866$   
 $knl = 1$  (zero step-static loading)  
-----  
NOTE: In expression (10-3) ' $V_s = A_v * fy * d / s$ ' is replaced by ' $V_s + f * V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).



= 1 (normal-weight concrete)  
Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 11.77537$   
 $V_u = 0.00051441$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.616$   
 $A_g = 300000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 140237.117$   
where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 61600.349$   
 $V_{sj1} = 61600.349$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{sj1}$  is multiplied by  $Col_{j1} = 0.60$   
 $s/d = 0.85$   
 $V_{sj2} = 0.00$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{sj2}$  is multiplied by  $Col_{j2} = 0.00$   
 $s/d = 1.59375$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$   
 $V_{s,c1} = 78636.768$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col_{c1} = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col_{c2} = 0.00$   
 $s/d = 1.5625$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
where  $a$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$   
 $b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$   
 $V_{Col0} = 653603.866$   
 $knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '

where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77482$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 140237.117$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 61600.349$

$V_{s,j1} = 61600.349$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $Col,j1 = 0.60$

$s/d = 0.85$

$V_{s,j2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $Col,j2 = 0.00$

$s/d = 1.59375$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 78636.768$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$

$s/d = 1.5625$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$

$b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At local axis: 3

```

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcjics

Constant Properties
-----
Knowledge Factor,   = 0.90
Mean strength values are used for both shear and moment calculations.
Consequently:
Jacket
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$ 
Concrete Elasticity,  $E_c = 26999.444$ 
Steel Elasticity,  $E_s = 200000.00$ 
Existing Column
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$ 
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$ 
Concrete Elasticity,  $E_c = 21019.039$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Jacket
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$ 
Existing Column
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$ 
#####
Max Height,  $H_{max} = 750.00$ 
Min Height,  $H_{min} = 400.00$ 
Max Width,  $W_{max} = 750.00$ 
Min Width,  $W_{min} = 400.00$ 
Jacket Thickness,  $t_j = 100.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.03889
Element Length,  $L = 3000.00$ 
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length  $l_o = 300.00$ 
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $\epsilon_{fu} = 0.01$ 
Number of directions,  $N_{oDir} = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $N_L = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
At local axis: 2
EDGE -A-
Shear Force,  $V_a = -0.00051441$ 
EDGE -B-
Shear Force,  $V_b = 0.00051441$ 
BOTH EDGES
Axial Force,  $F = -16273.616$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $A_{st} = 0.00$ 

```

-Compression:  $Asl_c = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $Asl_{ten} = 1137.257$   
 -Compression:  $Asl_{com} = 2208.54$   
 -Middle:  $Asl_{mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.81868759$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$   
 with  
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 8.0265E+008$   
 $Mu_{1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $Mu_{1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 8.0265E+008$   
 $Mu_{2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination  
 $Mu_{2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $Mu_{1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 8.9479397E-006$   
 $Mu = 4.8921E+008$

with full section properties:

$b = 750.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093001$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\phi_c \text{ (5A.5, TBDY)} = 0.002$   
 Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_c, \phi_c) = 0.01186911$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\phi_u = 0.01186911$   
 $\phi_{ue} \text{ ((5.4c), TBDY)} = \phi_u * \phi_{c, \text{min}} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.04377629$   
 where  $\phi = \phi_u * \phi_{c, \text{min}} * f_{ywe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.04286225$   
 Expression ((15B.6), TBDY) is modified as  $\phi_u = 1 - (\text{Unconfined area})/(\text{total area})$   
 $\phi_u = 0.31984848$   
 with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$   
 $b_{\text{max}} = 750.00$   
 $h_{\text{max}} = 750.00$   
 From EC8 A4.4.3(6),  $\phi_u = 2t_f/b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{f,e} = 870.5244$

$\phi_y = 0.04286225$   
 Expression ((15B.6), TBDY) is modified as  $\phi_u = 1 - (\text{Unconfined area})/(\text{total area})$   
 $\phi_u = 0.31984848$   
 with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$   
 $b_{\text{max}} = 750.00$   
 $h_{\text{max}} = 750.00$   
 From EC8 A4.4.3(6),  $\phi_u = 2t_f/b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{f,e} = 870.5244$

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_u, f = 1055.00$   
 $E_f = 64828.00$   
 $u, f = 0.015$   
 $ase((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.11512199$   
 $ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 0.87336895$   
 Expression (5.4d) for  $psh_{min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2(5.4d) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2((5.4d), TBDY) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$   
 $s1 = 510.00$   
 $s2 = 250.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$   
 $c$  = confinement factor = 1.03889

$y1 = 0.0014252$   
 $sh1 = 0.00456062$   
 $ft1 = 449.345$   
 $fy1 = 374.4542$   
 $su1 = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou_{min} = lb/d = 0.30798991$

$su1 = 0.4 \cdot esu1\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
 For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs\_jacket \cdot Asl\_ten\_jacket + fs\_core \cdot Asl\_ten\_core) / Asl\_ten = 374.4542$   
 with  $Es1 = (Es\_jacket \cdot Asl\_ten\_jacket + Es\_core \cdot Asl\_ten\_core) / Asl\_ten = 200000.00$   
 $y2 = 0.0014252$   
 $sh2 = 0.00456062$   
 $ft2 = 455.1997$   
 $fy2 = 379.3331$   
 $su2 = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou, min = lb/lb, min = 0.30798991$   
 $su2 = 0.4 \cdot esu2\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs\_jacket \cdot Asl\_com\_jacket + fs\_core \cdot Asl\_com\_core) / Asl\_com = 379.3331$   
 with  $Es2 = (Es\_jacket \cdot Asl\_com\_jacket + Es\_core \cdot Asl\_com\_core) / Asl\_com = 200000.00$   
 $yv = 0.0014252$   
 $shv = 0.00456062$   
 $ftv = 453.2097$   
 $fyv = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou, min = lb/ld = 0.30798991$   
 $suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs\_jacket \cdot Asl\_mid\_jacket + fs\_mid \cdot Asl\_mid\_core) / Asl\_mid = 377.6747$   
 with  $Esv = (Es\_jacket \cdot Asl\_mid\_jacket + Es\_mid \cdot Asl\_mid\_core) / Asl\_mid = 200000.00$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.02433675$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.04787748$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.04332854$

and confined core properties:

$b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.0276252$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.05434683$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.04918322$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.14216778$

$Mu = MRc (4.14) = 4.8921E+008$

$u = su (4.1) = 8.9479397E-006$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.30798991$

$lb = 300.00$

Id = 974.0579

Calculation of  $I_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

db = 16.66667

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 0.8418647

Atr = Min(Atr<sub>x</sub>, Atr<sub>y</sub>) = 257.6106

where Atr<sub>x</sub>, Atr<sub>y</sub> are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s<sub>external</sub>, s<sub>internal</sub>) = 510.00

n = 24.00

Calculation of Mu1-

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 9.7291088E-006$

Mu = 8.0265E+008

with full section properties:

b = 400.00

d = 707.00

d' = 43.00

v = 0.00174378

N = 16273.616

$f_c = 33.00$

$\phi_c$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = shear\_factor \cdot \max(\phi_u, \phi_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01186911$

we ((5.4c), TBDY) =  $ase \cdot \frac{sh_{min} \cdot f_{ywe}}{f_{ce}} + \min(f_x, f_y) = 0.04377629$

where  $f = af \cdot pf \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (Unconfined\ area) / (total\ area)$

$af = 0.31984848$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf / bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff_e = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (Unconfined\ area) / (total\ area)$

$af = 0.31984848$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf / bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff_e = 870.5244$

R = 40.00

Effective FRP thickness,  $tf = NL \cdot t \cdot \cos(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.11512199$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$$A_{sec} = 440000.00$$

$$s1 = 510.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0014252$$

$$sh1 = 0.00456062$$

$$ft1 = 455.1997$$

$$fy1 = 379.3331$$

$$su1 = 0.00542681$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30798991$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (f_{sjacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 379.3331$$



$$\text{with } Es1 = (Es_{\text{jacket}} \cdot Asl_{\text{ten,jacket}} + Es_{\text{core}} \cdot Asl_{\text{ten,core}}) / Asl_{\text{ten}} = 200000.00$$

$$y2 = 0.0014252$$

$$sh2 = 0.00456062$$

$$ft2 = 449.345$$

$$fy2 = 374.4542$$

$$su2 = 0.00542681$$
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  

$$\text{Shear\_factor} = 1.00$$

$$lo/lo_{\text{min}} = lb/lb_{\text{min}} = 0.30798991$$

$$su2 = 0.4 \cdot esu2_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$$
 From table 5A.1, TBDY:  $esu2_{\text{nominal}} = 0.08$ ,  
 For calculation of  $esu2_{\text{nominal}}$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  

$$\text{with } fs2 = (fs_{\text{jacket}} \cdot Asl_{\text{com,jacket}} + fs_{\text{core}} \cdot Asl_{\text{com,core}}) / Asl_{\text{com}} = 374.4542$$

$$\text{with } Es2 = (Es_{\text{jacket}} \cdot Asl_{\text{com,jacket}} + Es_{\text{core}} \cdot Asl_{\text{com,core}}) / Asl_{\text{com}} = 200000.00$$

$$yv = 0.0014252$$

$$shv = 0.00456062$$

$$ftv = 453.2097$$

$$fyv = 377.6747$$

$$suv = 0.00542681$$
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  

$$\text{Shear\_factor} = 1.00$$

$$lo/lo_{\text{min}} = lb/ld = 0.30798991$$

$$suv = 0.4 \cdot esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$$
 From table 5A.1, TBDY:  $esuv_{\text{nominal}} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{\text{nominal}}$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  

$$\text{with } fsv = (fs_{\text{jacket}} \cdot Asl_{\text{mid,jacket}} + fs_{\text{mid}} \cdot Asl_{\text{mid,core}}) / Asl_{\text{mid}} = 377.6747$$

$$\text{with } Esv = (Es_{\text{jacket}} \cdot Asl_{\text{mid,jacket}} + Es_{\text{mid}} \cdot Asl_{\text{mid,core}}) / Asl_{\text{mid}} = 200000.00$$

$$1 = Asl_{\text{ten}} / (b \cdot d) \cdot (fs1 / fc) = 0.08977028$$

$$2 = Asl_{\text{com}} / (b \cdot d) \cdot (fs2 / fc) = 0.0456314$$

$$v = Asl_{\text{mid}} / (b \cdot d) \cdot (fsv / fc) = 0.08124101$$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc \text{ (5A.2, TBDY)} = 34.2833$   
 $cc \text{ (5A.5, TBDY)} = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{\text{ten}} / (b \cdot d) \cdot (fs1 / fc) = 0.11029209$   
 $2 = Asl_{\text{com}} / (b \cdot d) \cdot (fs2 / fc) = 0.05606291$   
 $v = Asl_{\text{mid}} / (b \cdot d) \cdot (fsv / fc) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su \text{ (4.9)} = 0.2110448$

$Mu = MRc \text{ (4.14)} = 8.0265E+008$

$u = su \text{ (4.1)} = 9.7291088E-006$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.30798991$

$lb = 300.00$

$ld = 974.0579$

Calculation of  $lb_{\text{min}}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{\text{jacket}} \cdot Area_{\text{jacket}} + fc'_{\text{core}} \cdot Area_{\text{core}}) / Area_{\text{section}} = 27.68182$ , but  $fc'^{0.5} < =$

8.3 MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$

$n = 24.00$

Calculation of  $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 8.9479397\text{E-}006$

$\mu_u = 4.8921\text{E+}008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

$\alpha_0$  (5A.5, TBDY) = 0.002

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.01186911$

$\mu_{ue}$  ((5.4c), TBDY) =  $\alpha_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$

where  $f = \alpha_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
Aconf,min1 = 71100.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 0.87336895$

Expression (5.4d) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 449.345

fy1 = 374.4542

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min =  $l_b/l_d = 0.30798991$

su1 =  $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,\text{jacket}} * A_{s,\text{ten,jacket}} + f_{s,\text{core}} * A_{s,\text{ten,core}}) / A_{s,\text{ten}} = 374.4542$

with Es1 =  $(E_{s,\text{jacket}} * A_{s,\text{ten,jacket}} + E_{s,\text{core}} * A_{s,\text{ten,core}}) / A_{s,\text{ten}} = 200000.00$

y2 = 0.0014252

sh2 = 0.00456062

ft2 = 455.1997

fy2 = 379.3331

su2 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 379.3331$   
 with  $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / f_c) = 0.02433675$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / f_c) = 0.04787748$   
 $v = A_{sl,mid} / (b * d) * (fs_v / f_c) = 0.04332854$   
 and confined core properties:  
 $b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / f_c) = 0.0276252$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / f_c) = 0.05434683$   
 $v = A_{sl,mid} / (b * d) * (fs_v / f_c) = 0.04918322$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.14216778$   
 $Mu = MRc (4.14) = 4.8921E+008$   
 $u = su (4.1) = 8.9479397E-006$

---

Calculation of ratio  $l_b/l_d$   
 -----  
 Lap Length:  $l_b/l_d = 0.30798991$   
 $l_b = 300.00$   
 $l_d = 974.0579$   
 Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} < =$   
 8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$$s = \max(s_{external}, s_{internal}) = 510.00$$

$$n = 24.00$$

Calculation of  $\mu_2$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.7291088E-006$$

$$\mu_u = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \max(\mu_u, \mu_c) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \mu_u = 0.01186911$$

$$\mu_{ue} ((5.4c), \text{TB DY}) = \alpha_{se} * \mu_{sh, \min} * f_{ywe} / f_{ce} + \min(f_x, f_y) = 0.04377629$$

where  $f = \alpha_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} ((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$\alpha_{se1} = \max(((A_{conf, \max 1} - A_{noConf1}) / A_{conf, \max 1}) * (A_{conf, \min 1} / A_{conf, \max 1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf, \min 1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf, \max 1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 510.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0014252$$

$$sh1 = 0.00456062$$

$$ft1 = 455.1997$$

$$fy1 = 379.3331$$

$$su1 = 0.00542681$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30798991$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{nominal} = 0.08,$$

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 379.3331$$

$$\text{with } Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$$

$$y2 = 0.0014252$$

$$sh2 = 0.00456062$$

$$ft2 = 449.345$$

$$fy2 = 374.4542$$

$$su2 = 0.00542681$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$$

$$su2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_{nominal} = 0.08,$$

For calculation of  $es_{u2\_nominal}$  and  $y_2$ ,  $sh_2$ ,  $ft_2$ ,  $fy_2$ , it is considered characteristic value  $fs_{y2} = fs_2/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 374.4542$

with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

$y_v = 0.0014252$

$sh_v = 0.00456062$

$ft_v = 453.2097$

$fy_v = 377.6747$

$suv = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.30798991$

$suv = 0.4 \cdot es_{u\_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $es_{u\_nominal} = 0.08$ ,

considering characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY

For calculation of  $es_{u\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 377.6747$

with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

$1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.08977028$

$2 = Asl_{com}/(b \cdot d) \cdot (fs_2/f_c) = 0.0456314$

$v = Asl_{mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.08124101$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.11029209$

$2 = Asl_{com}/(b \cdot d) \cdot (fs_2/f_c) = 0.05606291$

$v = Asl_{mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2110448$

$Mu = MRc (4.14) = 8.0265E+008$

$u = su (4.1) = 9.7291088E-006$

-----

Calculation of ratio  $lb/ld$

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Lap Length:  $lb/ld = 0.30798991$

$lb = 300.00$

$ld = 974.0579$

Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 510.00$

$n = 24.00$

-----

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Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 653603.866$

Calculation of Shear Strength at edge 1,  $V_{r1} = 653603.866$

$V_{r1} = V_{Col} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 653603.866$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_{s+} + f * V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * \text{Area}_{jacket} + f_c'_{core} * \text{Area}_{core}) / \text{Area}_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 140237.117$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 61600.349$

$V_{sj1} = 0.00$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{sj1}$  is multiplied by  $Col_{j1} = 0.00$

$s/d = 1.59375$

$V_{sj2} = 61600.349$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{sj2}$  is multiplied by  $Col_{j2} = 0.60$

$s/d = 0.85$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col_{c1} = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78636.768$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col_{c2} = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 372533.843$

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe} ((11-5), \text{ACI } 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440



with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$   
 $bw = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 653603.866$   
 $knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 4.00$

$\mu_u = 11.78144$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 140237.117$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 61600.349$

$V_{sj1} = 0.00$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{sj1}$  is multiplied by  $Col_{j1} = 0.00$

$s/d = 1.59375$

$V_{sj2} = 61600.349$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{sj2}$  is multiplied by  $Col_{j2} = 0.60$

$s/d = 0.85$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col_{c1} = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78636.768$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col_{c2} = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), ACI 440) = 372533.843$

$f = 0.95$ , for fully-wrapped sections

$wf/sf = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $\theta$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta, a_i)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

fe = 0.004, from (11.6a), ACI 440  
with fu = 0.01  
From (11-11), ACI 440: Vs + Vf <= 838832.606  
bw = 400.00

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
At local axis: 3  
Integration Section: (a)  
Section Type: rcjls

#### Constant Properties

Knowledge Factor,  $\gamma = 0.90$   
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_b = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -2.3777E+007$   
Shear Force,  $V_2 = -7895.088$   
Shear Force,  $V_3 = 147.9095$   
Axial Force,  $F = -17072.715$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$

-Compression:  $Asl_{com} = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $Asl_{ten} = 1137.257$   
 -Compression:  $Asl_{com} = 2208.54$   
 -Middle:  $Asl_{mid} = 2007.478$   
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $Asl_{ten,jacket} = 829.3805$   
 -Compression:  $Asl_{com,jacket} = 1746.726$   
 -Middle:  $Asl_{mid,jacket} = 1545.664$   
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $Asl_{ten,core} = 307.8761$   
 -Compression:  $Asl_{com,core} = 461.8141$   
 -Middle:  $Asl_{mid,core} = 461.8141$   
 Mean Diameter of Tension Reinforcement,  $DbL = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = u = 0.03322088$   
 $u = y + p = 0.03691209$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00285336$  ((4.29), Biskinis Phd))  
 $M_y = 4.1188E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3011.649  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4491E+014$   
 $factor = 0.30$   
 $A_g = 440000.00$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.68182$   
 $N = 17072.715$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$   
 web width,  $b_w = 400.00$   
 flange thickness,  $t = 400.00$

$y = \min(y_{ten}, y_{com})$   
 $y_{ten} = 3.0743398E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \min(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 350.6021$   
 $d = 707.00$   
 $y = 0.19348343$   
 $A = 0.01018759$   
 $B = 0.004498$   
 with  $p_t = 0.00376294$   
 $p_c = 0.00416509$   
 $p_v = 0.00378591$   
 $N = 17072.715$   
 $b = 750.00$   
 $" = 0.06082037$   
 $y_{comp} = 1.6462519E-005$   
 with  $f'_c$  (12.3, (ACI 440)) = 33.48734  
 $f_c = 33.00$   
 $f_l = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $rc = 40.00$

$A_e/A_c = 0.31291181$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.19181501$   
 $A = 0.01002364$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.19279145 < t/d$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_d/l_d, \min = 0.38498739$

$l_b = 300.00$

$l_d = 779.2463$

Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \max(s_{\text{external}}, s_{\text{internal}}) = 510.00$

$n = 24.00$

- Calculation of  $p$  -

From table 10-8:  $p = 0.03405873$

with:

- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$

shear control ratio  $V_y E / V_{col} E = 0.81868759$

$d = d_{\text{external}} = 707.00$

$s = s_{\text{external}} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f / bw \cdot (f_{fe} / f_s) = 0.00376294$

jacket:  $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.000721$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 510.00$

core:  $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00067082$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2 \cdot t_f / bw \cdot (f_{fe} / f_s)$  is implemented to account for FRP contribution

where  $f = 2 \cdot t_f / bw$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation  $f_s$  of jacket is used.

$NUD = 17072.715$

$A_g = 440000.00$

$f_{cE} = (f_{c_{\text{jacket}}} \cdot \text{Area}_{\text{jacket}} + f_{c_{\text{core}}} \cdot \text{Area}_{\text{core}}) / \text{section\_area} = 27.68182$

$f_{yIE} = (f_{y_{\text{ext\_Long\_Reinf}}} \cdot \text{Area}_{\text{ext\_Long\_Reinf}} + f_{y_{\text{int\_Long\_Reinf}}} \cdot \text{Area}_{\text{int\_Long\_Reinf}}) / \text{Area}_{\text{Tot\_Long\_Rein}} = 529.9972$

$f_{yIE} = (f_{y_{\text{ext\_Trans\_Reinf}}} \cdot s_1 + f_{y_{\text{int\_Trans\_Reinf}}} \cdot s_2) / (s_1 + s_2) = 502.0032$

$p_l = \text{Area}_{\text{Tot\_Long\_Rein}} / (b \cdot d) = 0.01009575$

$b = 750.00$

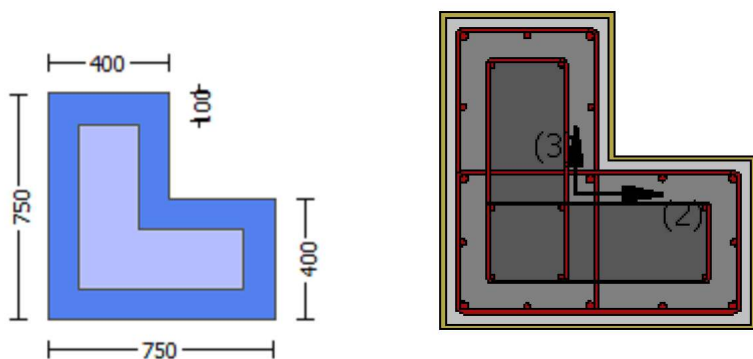
$d = 707.00$

$f_{cE} = 27.68182$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
At local axis: 3  
Integration Section: (a)

## Calculation No. 13

column C1, Floor 1  
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)  
Analysis: Uniform +X  
Check: Shear capacity  $V_{Rd}$   
Edge: End  
Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1  
At local axis: 2  
Integration Section: (b)  
Section Type: rcjcs

### Constant Properties

Knowledge Factor,  $\gamma = 0.90$   
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.  
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$   
Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$   
#####  
Note: Especially for the calculation of  $\mu_y$  for displacement ductility demand,  
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as  
Deformation-Controlled Action (Table C7-1, ASCE 41-17).  
Jacket  
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
Existing Column  
Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = l_b = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

EDGE -A-  
Bending Moment,  $M_a = -2.3777E+007$   
Shear Force,  $V_a = -7895.088$   
EDGE -B-  
Bending Moment,  $M_b = 86052.109$   
Shear Force,  $V_b = 7895.088$   
BOTH EDGES  
Axial Force,  $F = -17072.715$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 5353.274$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1137.257$   
-Compression:  $A_{sl,com} = 2208.54$   
-Middle:  $A_{sl,mid} = 2007.478$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 684489.848$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n l^* V_{CoI0} = 760544.275$   
 $V_{CoI} = 760544.275$   
 $k_n l = 1.00$   
displacement\_ductility\_demand = 0.08726657

NOTE: In expression (10-3) ' $V_s = A_v f_y d/s$ ' is replaced by ' $V_{s+} = f^* V_f$ '

where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 21.31818$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 86052.109$

$V_u = 7895.088$

$d = 0.8 \cdot h = 600.00$

$N_u = 17072.715$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 126213.67$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 55439.87$

$V_{s,j1} = 0.00$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 510.00$

$V_{s,j1}$  is multiplied by  $Col,j1 = 0.00$

$s/d = 1.59375$

$V_{s,j2} = 55439.87$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 510.00$

$V_{s,j2}$  is multiplied by  $Col,j2 = 0.60$

$s/d = 0.85$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 70773.799$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 70773.799$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$

$s/d = 0.56818182$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,

where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 736127.561$

$b_w = 400.00$

displacement\_ductility\_demand is calculated as  $\delta / y$

- Calculation of  $\delta / y$  for END B -  
for rotation axis 3 and integ. section (b)

From analysis, chord rotation =  $2.4803980\text{E}-005$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00028423$  ((4.29), Biskinis Phd))  
 $M_y = 4.1188\text{E}+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $300.00$   
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 1.4491\text{E}+014$   
 $\text{factor} = 0.30$   
 $A_g = 440000.00$   
 Mean concrete strength:  $f'_c = (f'_{c\_jacket} * \text{Area}_{jacket} + f'_{c\_core} * \text{Area}_{core}) / \text{Area}_{section} = 27.68182$   
 $N = 17072.715$   
 $E_c * I_g = E_{c\_jacket} * I_{g\_jacket} + E_{c\_core} * I_{g\_core} = 4.8303\text{E}+014$

#### Calculation of Yielding Moment $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$   
 web width,  $b_w = 400.00$   
 flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 3.0743398\text{E}-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 350.6021$   
 $d = 707.00$   
 $y = 0.19348343$   
 $A = 0.01018759$   
 $B = 0.004498$   
 with  $p_t = 0.00214476$   
 $p_c = 0.00416509$   
 $p_v = 0.00378591$   
 $N = 17072.715$   
 $b = 750.00$   
 $" = 0.06082037$   
 $y_{comp} = 1.6462519\text{E}-005$   
 with  $f'_c$  (12.3, (ACI 440)) =  $33.48734$   
 $f'_c = 33.00$   
 $f_l = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $r_c = 40.00$   
 $A_e / A_c = 0.31291181$   
 Effective FRP thickness,  $t_f = N L * t * \text{Cos}(\theta_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.19181501$   
 $A = 0.01002364$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.19279145 < t/d$

#### Calculation of ratio $I_b / I_d$

Lap Length:  $I_d / I_{d,min} = 0.38498739$   
 $I_b = 300.00$   
 $I_d = 779.2463$   
 Calculation of  $I$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $\delta_b = 16.66667$

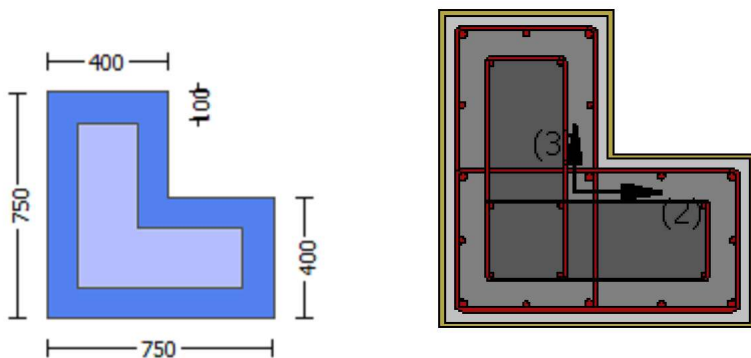


Mean strength value of all re-bars:  $f_y = 524.4464$   
Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1  
At local axis: 2  
Integration Section: (b)

## Calculation No. 14

column C1, Floor 1  
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)  
Analysis: Uniform +X  
Check: Chord rotation capacity (  $\phi$  )  
Edge: End  
Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
At Shear local axis: 3  
(Bending local axis: 2)  
Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\phi = 0.90$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Jacket  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.03889  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $e_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

-----  
 Stepwise Properties  
 -----

At local axis: 3  
 EDGE -A-  
 Shear Force,  $V_a = -0.00051441$   
 EDGE -B-  
 Shear Force,  $V_b = 0.00051441$   
 BOTH EDGES  
 Axial Force,  $F = -16273.616$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
     -Tension:  $As_t = 0.00$   
     -Compression:  $As_c = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
     -Tension:  $As_{t,ten} = 1137.257$   
     -Compression:  $As_{l,com} = 2208.54$   
     -Middle:  $As_{l,mid} = 2007.478$

-----  
 -----  
 Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.81868759$   
 Member Controlled by Flexure ( $V_e/V_r < 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$

with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.0265E+008$   
 $M_{u1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $M_{u1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.0265E+008$   
 $M_{u2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination  
 $M_{u2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

-----  
Calculation of  $M_{u1+}$   
-----

-----  
Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 8.9479397E-006$   
 $M_u = 4.8921E+008$   
-----

with full section properties:

$b = 750.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093001$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\phi_c \text{ (5A.5, TBDY)} = 0.002$

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01186911$

$\phi_{ue} \text{ ((5.4c), TBDY)} = a_{se} * \phi_{u,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.04377629$

where  $\phi_{fx} = a_f * \phi_{pf} * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $\phi_{fx} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A4.4.3(6),  $\phi_{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

-----  
 $\phi_{fy} = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A4.4.3(6),  $\phi_{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

-----  
 $R = 40.00$

Effective FRP thickness,  $t_f = N_L * t * \cos(\theta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\phi_{u,f} = 0.015$

$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.11512199$

$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.11081094$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2})*(A_{conf,min2}/A_{conf,max2}),0) = 0.12134906$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min}*F_{ywe} = \text{Min}(psh_x*F_{ywe}, psh_y*F_{ywe}) = 0.87336895$   
 Expression (5.4d) for  $psh_{min}*F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1 ((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 (5.4d) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1 ((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$   
 $s1 = 510.00$   
 $s2 = 250.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$   
 $c$  = confinement factor = 1.03889  
 $y1 = 0.0014252$   
 $sh1 = 0.00456062$   
 $ft1 = 449.345$   
 $fy1 = 374.4542$   
 $su1 = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $lo/lo_{min} = lb/ld = 0.30798991$   
 $su1 = 0.4*es_{u1\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $es_{u1\_nominal} = 0.08$ ,  
 For calculation of  $es_{u1\_nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs_{jacket}*A_{sl,ten,jacket} + fs_{core}*A_{sl,ten,core})/A_{sl,ten} = 374.4542$   
 with  $Es1 = (Es_{jacket}*A_{sl,ten,jacket} + Es_{core}*A_{sl,ten,core})/A_{sl,ten} = 200000.00$   
 $y2 = 0.0014252$   
 $sh2 = 0.00456062$   
 $ft2 = 455.1997$   
 $fy2 = 379.3331$   
 $su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 379.3331$   
 with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.02433675$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04787748$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.04332854$   
 and confined core properties:  
 $b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0276252$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05434683$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.04918322$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.14216778$   
 $Mu = MRc (4.14) = 4.8921E+008$   
 $u = su (4.1) = 8.9479397E-006$

---

Calculation of ratio  $l_b/l_d$   
 -----  
 Lap Length:  $l_b/l_d = 0.30798991$   
 $l_b = 300.00$   
 $l_d = 974.0579$   
 Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq$   
 8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$$

$$n = 24.00$$

Calculation of  $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.7291088E-006$$

$$\mu_1 = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha_1(5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_1: \mu_1^* = \text{shear\_factor} * \text{Max}(\mu_1, \mu_2) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_1 = 0.01186911$$

$$\mu_2 \text{ ((5.4c), TBDY) } = \alpha_1 * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$$

where  $f = \alpha_1 * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_1 = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_1 = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_1 = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_1 = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY) } = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 71100.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 510.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0014252$$

$$sh1 = 0.00456062$$

$$ft1 = 455.1997$$

$$fy1 = 379.3331$$

$$su1 = 0.00542681$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.30798991$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{nominal} = 0.08,$$

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 379.3331$$

$$\text{with } Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$$

$$y2 = 0.0014252$$

$$sh2 = 0.00456062$$

$$ft2 = 449.345$$

$$fy2 = 374.4542$$

$$su2 = 0.00542681$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$$

$$su2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_{nominal} = 0.08,$$

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs\_jacket \cdot Asl\_com\_jacket + fs\_core \cdot Asl\_com\_core) / Asl\_com = 374.4542$

with  $Es2 = (Es\_jacket \cdot Asl\_com\_jacket + Es\_core \cdot Asl\_com\_core) / Asl\_com = 200000.00$

$yv = 0.0014252$

$shv = 0.00456062$

$ftv = 453.2097$

$fyv = 377.6747$

$suv = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.30798991$

$suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fsv = (fs\_jacket \cdot Asl\_mid\_jacket + fs\_mid \cdot Asl\_mid\_core) / Asl\_mid = 377.6747$

with  $Es_v = (Es\_jacket \cdot Asl\_mid\_jacket + Es\_mid \cdot Asl\_mid\_core) / Asl\_mid = 200000.00$

$1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.08977028$

$2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.0456314$

$v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.08124101$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.11029209$

$2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.05606291$

$v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2110448$

$Mu = MRc (4.14) = 8.0265E+008$

$u = su (4.1) = 9.7291088E-006$

-----

Calculation of ratio  $lb/ld$

-----

Lap Length:  $lb/ld = 0.30798991$

$lb = 300.00$

$ld = 974.0579$

Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_jacket \cdot Area\_jacket + fc'_core \cdot Area\_core) / Area\_section = 27.68182$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 0.8418647$

$Atr = Min(Atr\_x, Atr\_y) = 257.6106$

where  $Atr\_x, Atr\_y$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = Max(s\_external, s\_internal) = 510.00$

$n = 24.00$

-----

-----



## Calculation of $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.9479397E-006$$

$$\mu_{2+} = 4.8921E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$\nu = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha_{co} (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_{cu}: \mu_{cu} = \text{shear\_factor} * \text{Max}(\mu_{cu}, \alpha_{co}) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.01186911$$

$$\mu_{ve} ((5.4c), TBDY) = \alpha_{se} * \mu_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.04377629$$

where  $\mu_f = \alpha_f * \mu_{pf} * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A4.4.3(6), } \mu_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\mu_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A4.4.3(6), } \mu_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

$$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 71100.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (>= \alpha_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.12134906$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.000721$   
 $Lstir1$  (Length of stirrups along Y) = 2060.00  
 $Astir1$  (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00067082$   
 $Lstir2$  (Length of stirrups along Y) = 1468.00  
 $Astir2$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.000721$   
 $Lstir1$  (Length of stirrups along X) = 2060.00  
 $Astir1$  (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00067082$   
 $Lstir2$  (Length of stirrups along X) = 1468.00  
 $Astir2$  (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 449.345

fy1 = 374.4542

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30798991

su1 =  $0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 374.4542$

with Es1 =  $(Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$

y2 = 0.0014252

sh2 = 0.00456062

ft2 = 455.1997

fy2 = 379.3331

su2 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30798991

su2 =  $0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 =  $(fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 379.3331$

with Es2 =  $(Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

yv = 0.0014252

```

shv = 0.00456062
ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 0.30798991
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
    2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
    v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
    c = confinement factor = 1.03889
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
    2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
    v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.30798991
lb = 300.00
ld = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 0.8418647
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 510.00
n = 24.00
-----
-----
-----
Calculation of Mu2-
-----
-----
-----
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

```

u = 9.7291088E-006  
Mu = 8.0265E+008

with full section properties:

b = 400.00  
d = 707.00  
d' = 43.00  
v = 0.00174378  
N = 16273.616  
fc = 33.00  
co (5A.5, TBDY) = 0.002

Final value of cu:  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $cu = 0.01186911$

we ((5.4c), TBDY) =  $ase * sh, \min * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.04377629$

where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$fx = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A 4.4.3(6),  $pf = 2tf / bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff_e = 870.5244$

$fy = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A 4.4.3(6),  $pf = 2tf / bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff_e = 870.5244$

$R = 40.00$

Effective FRP thickness,  $tf = NL * t * \cos(b1) = 1.016$

$fu_f = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.11512199$

$ase1 = \text{Max}(((A_{conf, \max 1} - A_{noConf1}) / A_{conf, \max 1}) * (A_{conf, \min 1} / A_{conf, \max 1}), 0) = 0.11081094$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf, \min 1} = 71100.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf, \max 1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $bi^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf, \max 2} - A_{noConf2}) / A_{conf, \max 2}) * (A_{conf, \min 2} / A_{conf, \max 2}), 0) = 0.12134906$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf, \min 2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf, \max 2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $bi^2/6$  as defined at (A.2).

$psh_{min} \cdot F_{ywe} = \min(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 0.87336895$   
 Expression (5.4d) for  $psh_{min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$   
 $s1 = 510.00$   
 $s2 = 250.00$

$f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$

$y1 = 0.0014252$   
 $sh1 = 0.00456062$   
 $ft1 = 455.1997$   
 $fy1 = 379.3331$   
 $su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$

$lo/lou, min = lb/ld = 0.30798991$

$su1 = 0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket} \cdot A_{sl, ten, jacket} + fs_{core} \cdot A_{sl, ten, core}) / A_{sl, ten} = 379.3331$

with  $Es1 = (Es_{jacket} \cdot A_{sl, ten, jacket} + Es_{core} \cdot A_{sl, ten, core}) / A_{sl, ten} = 200000.00$

$y2 = 0.0014252$   
 $sh2 = 0.00456062$   
 $ft2 = 449.345$   
 $fy2 = 374.4542$   
 $su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$

$lo/lou, min = lb/lb, min = 0.30798991$

$su2 = 0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs_{jacket} \cdot A_{sl, com, jacket} + fs_{core} \cdot A_{sl, com, core}) / A_{sl, com} = 374.4542$

with  $Es2 = (Es_{jacket} \cdot A_{sl, com, jacket} + Es_{core} \cdot A_{sl, com, core}) / A_{sl, com} = 200000.00$

$yv = 0.0014252$   
 $shv = 0.00456062$   
 $ftv = 453.2097$   
 $fyv = 377.6747$   
 $suv = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with

$\text{Shear\_factor} = 1.00$   
 $\text{lb}/\text{ld}, \text{min} = \text{lb}/\text{ld} = 0.30798991$   
 $\text{suv} = 0.4 * \text{esuv\_nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $\text{esuv\_nominal} = 0.08$ ,  
 considering characteristic value  $\text{fsyv} = \text{fsv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $\text{esuv\_nominal}$  and  $\text{yv}$ ,  $\text{shv}$ ,  $\text{ftv}$ ,  $\text{fyv}$ , it is considered  
 characteristic value  $\text{fsyv} = \text{fsv}/1.2$ , from table 5.1, TBDY.  
 $\text{y1}$ ,  $\text{sh1}$ ,  $\text{ft1}$ ,  $\text{fy1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $\text{fsv} = (\text{fs}_{\text{jacket}} * \text{Asl}_{\text{mid,jacket}} + \text{fs}_{\text{mid}} * \text{Asl}_{\text{mid,core}}) / \text{Asl}_{\text{mid}} = 377.6747$   
 with  $\text{Esv} = (\text{Es}_{\text{jacket}} * \text{Asl}_{\text{mid,jacket}} + \text{Es}_{\text{mid}} * \text{Asl}_{\text{mid,core}}) / \text{Asl}_{\text{mid}} = 200000.00$   
 $1 = \text{Asl}_{\text{ten}} / (\text{b} * \text{d}) * (\text{fs1}/\text{fc}) = 0.08977028$   
 $2 = \text{Asl}_{\text{com}} / (\text{b} * \text{d}) * (\text{fs2}/\text{fc}) = 0.0456314$   
 $v = \text{Asl}_{\text{mid}} / (\text{b} * \text{d}) * (\text{fsv}/\text{fc}) = 0.08124101$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $\text{fcc} (5A.2, \text{TBDY}) = 34.2833$   
 $\text{cc} (5A.5, \text{TBDY}) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = \text{Asl}_{\text{ten}} / (\text{b} * \text{d}) * (\text{fs1}/\text{fc}) = 0.11029209$   
 $2 = \text{Asl}_{\text{com}} / (\text{b} * \text{d}) * (\text{fs2}/\text{fc}) = 0.05606291$   
 $v = \text{Asl}_{\text{mid}} / (\text{b} * \text{d}) * (\text{fsv}/\text{fc}) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

---->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 ---->  
 $\text{su} (4.9) = 0.2110448$   
 $\text{Mu} = \text{MRc} (4.14) = 8.0265\text{E}+008$   
 $u = \text{su} (4.1) = 9.7291088\text{E}-006$

Calculation of ratio  $\text{lb}/\text{ld}$

Lap Length:  $\text{lb}/\text{ld} = 0.30798991$   
 $\text{lb} = 300.00$   
 $\text{ld} = 974.0579$   
 Calculation of  $\text{lb}, \text{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $\text{db} = 16.66667$   
 Mean strength value of all re-bars:  $\text{fy} = 655.558$   
 Mean concrete strength:  $\text{fc}' = (\text{fc}'_{\text{jacket}} * \text{Area}_{\text{jacket}} + \text{fc}'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $\text{fc}'^{0.5} \leq$   
 $8.3 \text{ MPa} (22.5.3.1, \text{ACI } 318-14)$   
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $\text{cb} = 25.00$   
 $\text{Ktr} = 0.8418647$   
 $\text{Atr} = \text{Min}(\text{Atr}_x, \text{Atr}_y) = 257.6106$   
 where  $\text{Atr}_x$ ,  $\text{Atr}_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

Calculation of Shear Strength  $\text{Vr} = \text{Min}(\text{Vr1}, \text{Vr2}) = 653603.866$

Calculation of Shear Strength at edge 1,  $\text{Vr1} = 653603.866$   
 $\text{Vr1} = \text{VCol} ((10.3), \text{ASCE } 41-17) = \text{knl} * \text{VCol0}$   
 $\text{VCol0} = 653603.866$   
 $\text{knl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $\text{Vs} = \text{Av} * \text{fy} * \text{d}/\text{s}$ ' is replaced by ' $\text{Vs} + \text{f} * \text{Vf}$ '  
 where  $\text{Vf}$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)  
Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 11.77537$   
 $V_u = 0.00051441$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.616$   
 $A_g = 300000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 140237.117$   
where:  
 $V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 61600.349$   
 $V_{s,j1} = 61600.349$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{s,j1}$  is multiplied by  $\text{Col},j1 = 0.60$   
 $s/d = 0.85$   
 $V_{s,j2} = 0.00$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{s,j2}$  is multiplied by  $\text{Col},j2 = 0.00$   
 $s/d = 1.59375$   
 $V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78636.768$   
 $V_{s,c1} = 78636.768$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $\text{Col},c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $\text{Col},c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
where  $a$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$   
 $b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$   
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{\text{Col}0}$   
 $V_{\text{Col}0} = 653603.866$   
 $k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)  
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 11.77482$   
 $V_u = 0.00051441$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.616$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 140237.117$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 61600.349$   
 $V_{sj1} = 61600.349$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 0.60$   
 $s/d = 0.85$   
 $V_{sj2} = 0.00$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 0.00$   
 $s/d = 1.59375$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$   
 $V_{s,c1} = 78636.768$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / NoDir = 1.016$   
 $df_v = d$  (figure 11.2, ACI 440) = 707.00  
 $ffe ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$   
 $bw = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At local axis: 3



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjcs

Constant Properties

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Knowledge Factor,  $\gamma = 0.90$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Jacket  
 New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.03889  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

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Stepwise Properties

---

At local axis: 2  
 EDGE -A-  
 Shear Force,  $V_a = -0.00051441$   
 EDGE -B-  
 Shear Force,  $V_b = 0.00051441$   
 BOTH EDGES  
 Axial Force,  $F = -16273.616$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $A_{st} = 0.00$   
 -Compression:  $A_{sc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{s,ten} = 1137.257$

-Compression:  $A_{s,com} = 2208.54$

-Middle:  $A_{s,mid} = 2007.478$

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.81868759$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.0265E+008$

$M_{u1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.0265E+008$

$M_{u2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $M_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 8.9479397E-006$

$M_u = 4.8921E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

$\phi_c$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_c, \phi_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01186911$

we ((5.4c), TBDY) =  $a_s e * \phi_{u,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.04377629$

where  $\phi = a_f * \phi_p * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A4.4.3(6),  $\phi_p = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$\phi_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A4.4.3(6),  $\phi_p = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_f = 0.015$   
 $ase \ ((5.4d), TBDY) = (ase_1 \cdot A_{ext} + ase_2 \cdot A_{int}) / A_{sec} = 0.11512199$   
 $ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$   
The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase_2 \ (\geq ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$   
The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 0.87336895$   
Expression (5.4d) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 0.87336895$   
 $p_{sh1} \ ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2} \ ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548  
-----

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 0.87336895$   
 $p_{sh1} \ ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2} \ ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548  
-----

$A_{sec} = 440000.00$   
 $s_1 = 510.00$   
 $s_2 = 250.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$   
 $c$  = confinement factor = 1.03889

$y_1 = 0.0014252$   
 $sh_1 = 0.00456062$   
 $ft_1 = 449.345$   
 $fy_1 = 374.4542$   
 $su_1 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 0.30798991$   
 $su_1 = 0.4 \cdot esu_{1,nominal} \ ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = (fs\_jacket \cdot Asl\_ten\_jacket + fs\_core \cdot Asl\_ten\_core) / Asl\_ten = 374.4542$   
with  $Es1 = (Es\_jacket \cdot Asl\_ten\_jacket + Es\_core \cdot Asl\_ten\_core) / Asl\_ten = 200000.00$   
 $y2 = 0.0014252$   
 $sh2 = 0.00456062$   
 $ft2 = 455.1997$   
 $fy2 = 379.3331$   
 $su2 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lou, min = lb/lb, min = 0.30798991$   
 $su2 = 0.4 \cdot esu2\_nominal \cdot ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs2 = (fs\_jacket \cdot Asl\_com\_jacket + fs\_core \cdot Asl\_com\_core) / Asl\_com = 379.3331$   
with  $Es2 = (Es\_jacket \cdot Asl\_com\_jacket + Es\_core \cdot Asl\_com\_core) / Asl\_com = 200000.00$   
 $yv = 0.0014252$   
 $shv = 0.00456062$   
 $ftv = 453.2097$   
 $fyv = 377.6747$   
 $suv = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lou, min = lb/ld = 0.30798991$   
 $suv = 0.4 \cdot esuv\_nominal \cdot ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs\_jacket \cdot Asl\_mid\_jacket + fs\_mid \cdot Asl\_mid\_core) / Asl\_mid = 377.6747$   
with  $Esv = (Es\_jacket \cdot Asl\_mid\_jacket + Es\_mid \cdot Asl\_mid\_core) / Asl\_mid = 200000.00$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.02433675$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.04787748$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.04332854$

and confined core properties:

$b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.0276252$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.05434683$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.04918322$

Case/Assumption: Unconfined full section - Steel rupture  
'satisfies Eq. (4.3)

--->

$v < vs, y2$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.14216778$   
 $Mu = MRc (4.14) = 4.8921E+008$   
 $u = su (4.1) = 8.9479397E-006$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.30798991$   
 $lb = 300.00$   
 $ld = 974.0579$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 0.8418647$$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \max(s_{external}, s_{internal}) = 510.00$$

$$n = 24.00$$

Calculation of  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$\mu_u = 9.7291088E-006$$

$$\mu_u = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} \cdot \max(\mu_u, \mu_c) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \mu_u = 0.01186911$$

$$\text{we ((5.4c), TB DY) } = a_{se} \cdot \frac{\min(f_{ywe}, f_{ce})}{f_{ce}} + \min(f_x, f_y) = 0.04377629$$

where  $f = a_f \cdot p_f \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TB DY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TB DY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L \cdot t \cdot \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\text{ase ((5.4d), TB DY) } = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int}) / A_{sec} = 0.11512199$$

$$a_{se1} = \max(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 71100.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{NoConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 0.87336895$

Expression (5.4d) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895

psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 455.1997

fy1 = 379.3331

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

lo/lou,min = lb/lb = 0.30798991

su1 =  $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 379.3331$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y_2 = 0.0014252$   
 $sh_2 = 0.00456062$   
 $ft_2 = 449.345$   
 $fy_2 = 374.4542$   
 $su_2 = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lo_{min} = lb/lb_{min} = 0.30798991$   
 $su_2 = 0.4 * esu_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{nominal} = 0.08$ ,  
 For calculation of  $esu_{nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fs_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 374.4542$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lo_{min} = lb/ld = 0.30798991$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fs_v = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fs_v = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.08977028$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.0456314$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.08124101$   
 and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.11029209$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05606291$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.2110448$   
 $Mu = MRc (4.14) = 8.0265E+008$   
 $u = su (4.1) = 9.7291088E-006$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.30798991$   
 $lb = 300.00$   
 $ld = 974.0579$   
 Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
 where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

#### Calculation of $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 8.9479397\text{E-}006$   
 $\mu = 4.8921\text{E+}008$

with full section properties:

$b = 750.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093001$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha (5A.5, \text{TBDY}) = 0.002$   
 Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01186911$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\mu = 0.01186911$   
 $\mu (5.4c, \text{TBDY}) = \alpha * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$   
 where  $f = \alpha * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{f,f} = 0.015$

$\alpha_{se} ((5.4d), \text{TBDY}) = (\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and



is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and  
is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length  
equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2})*(A_{conf,min2}/A_{conf,max2}),0) = 0.12134906$   
The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization  
of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)  
"Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and  
is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and  
is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length  
equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min}*F_{ywe} = \text{Min}(psh_x*F_{ywe}, psh_y*F_{ywe}) = 0.87336895$   
Expression (5.4d) for  $psh_{min}*F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without  
earthquake detailing (90° closed stirrups)

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 $psh_x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1 ((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 (5.4d) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548  
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 $psh_y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1 ((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548  
-----

-----  
 $A_{sec} = 440000.00$   
 $s1 = 510.00$   
 $s2 = 250.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$   
From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $y1 = 0.0014252$   
 $sh1 = 0.00456062$   
 $ft1 = 449.345$   
 $fy1 = 374.4542$   
 $su1 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $su1 = 0.4*es_{u1\_nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $es_{u1\_nominal} = 0.08$ ,  
For calculation of  $es_{u1\_nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fs_{y1} = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25*(l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = (f_{s,jacket}*A_{sl,ten,jacket} + f_{s,core}*A_{sl,ten,core})/A_{sl,ten} = 374.4542$   
with  $Es1 = (E_{s,jacket}*A_{sl,ten,jacket} + E_{s,core}*A_{sl,ten,core})/A_{sl,ten} = 200000.00$   
 $y2 = 0.0014252$   
 $sh2 = 0.00456062$   
 $ft2 = 455.1997$   
 $fy2 = 379.3331$   
 $su2 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 379.3331$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02433675$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.04787748$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.04332854$

and confined core properties:

$b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.0276252$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05434683$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.04918322$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.14216778$

$Mu = MRc (4.14) = 4.8921E+008$

$u = su (4.1) = 8.9479397E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$

$l_b = 300.00$

$l_d = 974.0579$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

#### Calculation of $\mu_2$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.7291088E-006$$

$$\mu_u = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha_{co} (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \alpha_{co}) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.01186911$$

$$\mu_{ve} ((5.4c), \text{TBDY}) = \alpha_{se} * \mu_u, \min(f_{yve}/f_{ce} + \min(f_x, f_y)) = 0.04377629$$

where  $f = \alpha_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$\alpha_{se} ((5.4d), \text{TBDY}) = (\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}})/A_{\text{sec}} = 0.11512199$$

$$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.11081094$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (>= \alpha_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  (5.4d) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 455.1997$

$fy1 = 379.3331$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.30798991$

$su1 = 0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket} \cdot A_{sl,ten,jacket} + fs_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 379.3331$

with  $Es1 = (Es_{jacket} \cdot A_{sl,ten,jacket} + Es_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 449.345$

$fy2 = 374.4542$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{u,min} = lb/lb_{min} = 0.30798991$

$su2 = 0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y2$ ,  $sh2$ ,  $ft2$ ,  $fy2$ , it is considered

characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 374.4542$   
 with  $Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.0014252$   
 $shv = 0.00456062$   
 $ftv = 453.2097$   
 $fyv = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou, min = lb/ld = 0.30798991$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.08977028$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.0456314$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.08124101$   
 and confined core properties:  
 $b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.11029209$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.05606291$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.099813$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.2110448$   
 $Mu = MRc (4.14) = 8.0265E+008$   
 $u = su (4.1) = 9.7291088E-006$   
 -----  
 Calculation of ratio  $lb/ld$   
 -----  
 Lap Length:  $lb/ld = 0.30798991$   
 $lb = 300.00$   
 $ld = 974.0579$   
 Calculation of  $lb, min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} < =$   
 8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 0.8418647$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$   
 -----  
 -----  
 -----

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 653603.866$

Calculation of Shear Strength at edge 1,  $V_{r1} = 653603.866$

$V_{r1} = V_{Col} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 653603.866$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} < = 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 140237.117$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 61600.349$

$V_{sj1} = 0.00$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{sj1}$  is multiplied by  $Col,j1 = 0.00$

$s/d = 1.59375$

$V_{sj2} = 61600.349$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{sj2}$  is multiplied by  $Col,j2 = 0.60$

$s/d = 0.85$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78636.768$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 372533.843$

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe} ((11-5), \text{ACI } 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$   
 $bw = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$   
 $V_{Col0} = 653603.866$   
 $k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)  
Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 11.78144$   
 $V_u = 0.00051441$   
 $d = 0.8 * h = 600.00$   
 $N_u = 16273.616$   
 $A_g = 300000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 140237.117$   
where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 61600.349$   
 $V_{sj1} = 0.00$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 0.00$   
 $s/d = 1.59375$   
 $V_{sj2} = 61600.349$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 0.60$   
 $s/d = 0.85$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 78636.768$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
where  $a$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$   
 $b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
At local axis: 2  
Integration Section: (b)  
Section Type: rcjls

#### Constant Properties

Knowledge Factor,  $\gamma = 0.90$   
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_b = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -138295.202$   
Shear Force,  $V_2 = 7895.088$   
Shear Force,  $V_3 = -147.9095$   
Axial Force,  $F = -17072.715$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 5353.274$



Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $Asl_{ten} = 1137.257$

-Compression:  $Asl_{com} = 2208.54$

-Middle:  $Asl_{mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $Asl_{ten,jacket} = 829.3805$

-Compression:  $Asl_{com,jacket} = 1746.726$

-Middle:  $Asl_{mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $Asl_{ten,core} = 307.8761$

-Compression:  $Asl_{com,core} = 461.8141$

-Middle:  $Asl_{mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement,  $DbL = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = u = 0.03145013$

$u = y + p = 0.03494459$

- Calculation of  $y$  -

$y = (My * Ls / 3) / E_{eff} = 0.00088586$  ((4.29), Biskinis Phd))

$My = 4.1188E+008$

$Ls = M/V$  (with  $Ls > 0.1 * L$  and  $Ls < 2 * L$ ) = 934.9988

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 17072.715$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment  $My$

Calculation of  $y$  and  $My$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$

web width,  $bw = 400.00$

flange thickness,  $t = 400.00$

$y = \min(y_{ten}, y_{com})$

$y_{ten} = 3.0743398E-006$

with ((10.1), ASCE 41-17)  $f_y = \min(f_y, 1.25 * f_y * (I_b / d)^{2/3}) = 350.6021$

$d = 707.00$

$y = 0.19348343$

$A = 0.01018759$

$B = 0.004498$

with  $pt = 0.00376294$

$pc = 0.00416509$

$pv = 0.00378591$

$N = 17072.715$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6462519E-005$

with  $fc' (12.3, (ACI 440)) = 33.48734$

$fc = 33.00$

$fl = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = pt + pc + pv = 0.01009575$

$rc = 40.00$

$A_e / A_c = 0.31291181$

Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.19181501$   
 $A = 0.01002364$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.19279145 < t/d$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.38498739$

$l_b = 300.00$

$l_d = 779.2463$

Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \max(s_{external}, s_{internal}) = 510.00$

$n = 24.00$

- Calculation of  $p$  -

From table 10-8:  $p = 0.03405873$

with:

- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$

shear control ratio  $V_y E / V_{col} E = 0.81868759$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f / bw \cdot (f_{fe} / f_s) = 0.00376294$

jacket:  $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.000721$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 510.00$

core:  $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00067082$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2 \cdot t_f / bw \cdot (f_{fe} / f_s)$  is implemented to account for FRP contribution

where  $f = 2 \cdot t_f / bw$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation  $f_s$  of jacket is used.

$NUD = 17072.715$

$A_g = 440000.00$

$f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section\_area = 27.68182$

$f_{yE} = (f_{y,ext\_Long\_Reinf} \cdot Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 529.9972$

$f_{yE} = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 502.0032$

$p_l = Area_{Tot\_Long\_Rein} / (b \cdot d) = 0.01009575$

$b = 750.00$

$d = 707.00$

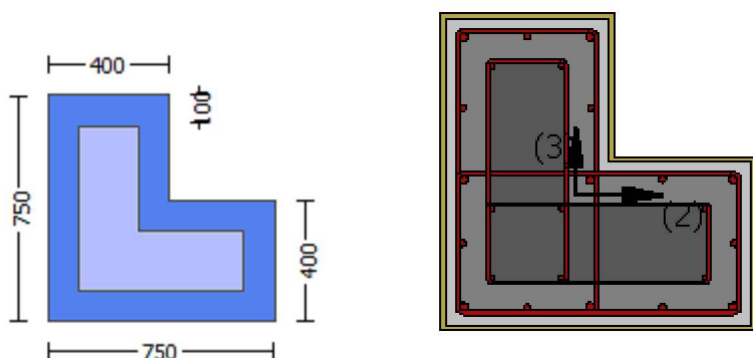
$f_{cE} = 27.68182$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
At local axis: 2  
Integration Section: (b)

-----

## Calculation No. 15

column C1, Floor 1  
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)  
Analysis: Uniform +X  
Check: Shear capacity  $V_{Rd}$   
Edge: End  
Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
Section Type: rcjls

### Constant Properties

-----

Knowledge Factor,  $\gamma = 0.90$   
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.  
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material: Steel Strength,  $f_s = f_{sm} = 555.56$

Existing Column

Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$

Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties

-----  
EDGE -A-

Bending Moment,  $M_a = -303215.468$

Shear Force,  $V_a = 147.9095$

EDGE -B-

Bending Moment,  $M_b = -138295.202$

Shear Force,  $V_b = -147.9095$

BOTH EDGES

Axial Force,  $F = -17072.715$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1137.257$

-Compression:  $As_{l,com} = 2208.54$

-Middle:  $As_{l,mid} = 2007.478$

Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

-----  
Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 684489.848$

$V_n$  ((10.3), ASCE 41-17) =  $k_n \phi V_{CoIO} = 760544.275$

$V_{CoI} = 760544.275$

$k_n = 1.00$

$\text{displacement\_ductility\_demand} = 3.3077552E-005$

-----  
NOTE: In expression (10-3) ' $V_s = A_v f_y d/s$ ' is replaced by ' $V_s + \phi V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 21.31818$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 138295.202$   
 $V_u = 147.9095$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 17072.715$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 126213.67$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 55439.87$   
 $V_{sj1} = 55439.87$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 510.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 0.60$   
 $s/d = 0.85$   
 $V_{sj2} = 0.00$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 510.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 0.00$   
 $s/d = 1.59375$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 70773.799$   
 $V_{s,c1} = 70773.799$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 400.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 400.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL \cdot t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 736127.561$   
 $b_w = 400.00$

displacement\_ductility\_demand is calculated as  $\Delta / y$

- Calculation of  $\Delta / y$  for END B -  
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation =  $2.9301958E-008$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00088586$  ((4.29), Biskinis Phd))  
 $M_y = 4.1188E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 934.9988  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4491E+014$   
 $factor = 0.30$   
 $A_g = 440000.00$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$   
 $N = 17072.715$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

#### Calculation of Yielding Moment $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$   
 web width,  $b_w = 400.00$   
 flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 3.0743398E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 350.6021$   
 $d = 707.00$   
 $y = 0.19348343$   
 $A = 0.01018759$   
 $B = 0.004498$   
 with  $p_t = 0.00214476$   
 $p_c = 0.00416509$   
 $p_v = 0.00378591$   
 $N = 17072.715$   
 $b = 750.00$   
 $" = 0.06082037$   
 $y_{comp} = 1.6462519E-005$   
 with  $f_c' (12.3, (ACI 440)) = 33.48734$   
 $f_c = 33.00$   
 $f_l = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $r_c = 40.00$   
 $A_e / A_c = 0.31291181$   
 Effective FRP thickness,  $t_f = N L * t * \cos(\theta_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.19181501$   
 $A = 0.01002364$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.19279145 < t/d$

#### Calculation of ratio $I_b / I_d$

Lap Length:  $I_d / I_{d,min} = 0.38498739$   
 $I_b = 300.00$   
 $I_d = 779.2463$   
 Calculation of  $I$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$

$n = 24.00$

-----  
End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 16

column C1, Floor 1

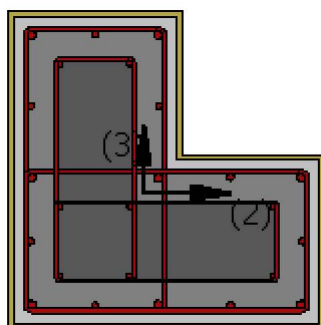
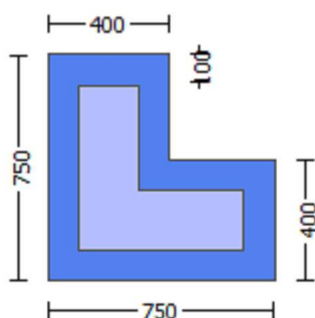
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

-----  
Knowledge Factor,  $\phi = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

```

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$ 
Concrete Elasticity,  $E_c = 26999.444$ 
Steel Elasticity,  $E_s = 200000.00$ 
Existing Column
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$ 
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$ 
Concrete Elasticity,  $E_c = 21019.039$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Jacket
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$ 
Existing Column
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$ 
#####
Max Height,  $H_{max} = 750.00$ 
Min Height,  $H_{min} = 400.00$ 
Max Width,  $W_{max} = 750.00$ 
Min Width,  $W_{min} = 400.00$ 
Jacket Thickness,  $t_j = 100.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.03889
Element Length,  $L = 3000.00$ 
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length  $l_o = 300.00$ 
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $ef_u = 0.01$ 
Number of directions,  $NoDir = 1$ 
Fiber orientations,  $bi: 0.00^\circ$ 
Number of layers,  $NL = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
At local axis: 3
EDGE -A-
Shear Force,  $V_a = -0.00051441$ 
EDGE -B-
Shear Force,  $V_b = 0.00051441$ 
BOTH EDGES
Axial Force,  $F = -16273.616$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $As_t = 0.00$ 
-Compression:  $As_c = 5353.274$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $As_{t,ten} = 1137.257$ 
-Compression:  $As_{c,com} = 2208.54$ 
-Middle:  $As_{l,mid} = 2007.478$ 
-----
-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.81868759$ 
Member Controlled by Flexure ( $V_e/V_r < 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$ 
with

```



$$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.0265E+008$$

$M_{u1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.0265E+008$$

$M_{u2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $M_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 8.9479397E-006$$

$$M_u = 4.8921E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\phi_{co} (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_{cu}: \phi_{cu} = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01186911$$

$$\phi_{we} ((5.4c), \text{TBDY}) = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.04377629$$

where  $\phi_f = a_f * \phi_{pf} * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A4.4.3(6), } \phi_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\phi_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A4.4.3(6), } \phi_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} ((5.4d), \text{TBDY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and  
is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length  
equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2})*(A_{conf,min2}/A_{conf,max2}),0) = 0.12134906$   
The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization  
of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)  
"Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and  
is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and  
is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length  
equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min}*F_{ywe} = \text{Min}(psh_x*F_{ywe}, psh_y*F_{ywe}) = 0.87336895$   
Expression (5.4d) for  $psh_{min}*F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without  
earthquake detailing (90° closed stirrups)

-----  
 $psh_x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1 ((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548  
-----

-----  
 $psh_y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 0.87336895$   
 $psh1 ((5.4d), TBDY) = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.000721$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548  
-----

-----  
 $A_{sec} = 440000.00$   
 $s1 = 510.00$   
 $s2 = 250.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$   
From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $y1 = 0.0014252$   
 $sh1 = 0.00456062$   
 $ft1 = 449.345$   
 $fy1 = 374.4542$   
 $su1 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou_{min} = lb/ld = 0.30798991$   
 $su1 = 0.4*es_{u1\_nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $es_{u1\_nominal} = 0.08$ ,  
For calculation of  $es_{u1\_nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fs_{y1} = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = (f_{s,jacket}*A_{s1,ten,jacket} + f_{s,core}*A_{s1,ten,core})/A_{s1,ten} = 374.4542$   
with  $Es1 = (E_{s,jacket}*A_{s1,ten,jacket} + E_{s,core}*A_{s1,ten,core})/A_{s1,ten} = 200000.00$   
 $y2 = 0.0014252$   
 $sh2 = 0.00456062$   
 $ft2 = 455.1997$   
 $fy2 = 379.3331$   
 $su2 = 0.00542681$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.30798991$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 379.3331$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0014252$   
 $sh_v = 0.00456062$   
 $ft_v = 453.2097$   
 $fy_v = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.30798991$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02433675$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.04787748$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.04332854$

and confined core properties:

$b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.0276252$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05434683$   
 $v = Asl_{mid} / (b * d) * (fs_v / fc) = 0.04918322$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.14216778$

$Mu = MRc (4.14) = 4.8921E+008$

$u = su (4.1) = 8.9479397E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$

$l_b = 300.00$

$l_d = 974.0579$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

#### Calculation of $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.7291088E-006$$

$$\mu_1 = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$c_0 \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_1: \mu_1^* = \text{shear\_factor} * \text{Max}(\mu_1, c_0) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_1 = 0.01186911$$

$$\text{we ((5.4c), TBDY)} = a_{se} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.12134906$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  (5.4d) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 455.1997$

$fy1 = 379.3331$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.30798991$

$su1 = 0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 379.3331$

with  $Es1 = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 449.345$

$fy2 = 374.4542$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{u,min} = lb/lb_{min} = 0.30798991$

$su2 = 0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y2$ ,  $sh2$ ,  $ft2$ ,  $fy2$ , it is considered

characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 374.4542$   
 with  $Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.0014252$   
 $shv = 0.00456062$   
 $ftv = 453.2097$   
 $fyv = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.30798991$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Esv = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1/fc) = 0.08977028$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2/fc) = 0.0456314$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv/fc) = 0.08124101$   
 and confined core properties:  
 $b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1/fc) = 0.11029209$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2/fc) = 0.05606291$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv/fc) = 0.099813$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.2110448$   
 $Mu = MRc (4.14) = 8.0265E+008$   
 $u = su (4.1) = 9.7291088E-006$   
 -----  
 Calculation of ratio  $lb/ld$   
 -----  
 Lap Length:  $lb/ld = 0.30798991$   
 $lb = 300.00$   
 $ld = 974.0579$   
 Calculation of  $lb,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} < =$   
 8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 0.8418647$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$   
 -----  
 -----  
 -----

## Calculation of $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 8.9479397E-006$$

$$\mu = 4.8921E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \mu = 0.01186911$$

$$\mu (5.4c, \text{TB DY}) = \alpha * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$$

where  $f = \alpha * \rho_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{f} = 0.015$$

$$\alpha_{se} ((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.11512199$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (\geq \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} \cdot F_{ywe} = \min(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d)) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 449.345$

$fy1 = 374.4542$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.30798991$

$su1 = 0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket} \cdot A_{sl,ten,jacket} + fs_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 374.4542$

with  $Es1 = (Es_{jacket} \cdot A_{sl,ten,jacket} + Es_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 455.1997$

$fy2 = 379.3331$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{u,min} = lb/lb_{min} = 0.30798991$

$su2 = 0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y2$ ,  $sh2$ ,  $ft2$ ,  $fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs_{jacket} \cdot A_{sl,com,jacket} + fs_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 379.3331$

with  $Es2 = (Es_{jacket} \cdot A_{sl,com,jacket} + Es_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$

$yv = 0.0014252$

$shv = 0.00456062$



```

ftv = 453.2097
fyv = 377.6747
suv = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 0.30798991
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
    with fsv = (fsjacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.02433675
    2 = Asl,com/(b*d)*(fs2/fc) = 0.04787748
    v = Asl,mid/(b*d)*(fsv/fc) = 0.04332854
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
    c = confinement factor = 1.03889
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.0276252
    2 = Asl,com/(b*d)*(fs2/fc) = 0.05434683
    v = Asl,mid/(b*d)*(fsv/fc) = 0.04918322
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.14216778
Mu = MRc (4.14) = 4.8921E+008
u = su (4.1) = 8.9479397E-006
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.30798991
lb = 300.00
ld = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 0.8418647
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 510.00
n = 24.00
-----
-----
-----
Calculation of Mu2-
-----
-----
-----
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 9.7291088E-006

```

$$\mu_u = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \alpha) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \mu_u = 0.01186911$$

$$\mu_{ue} ((5.4c), \text{TB DY}) = \alpha_{se} * \mu_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.04377629$$

where  $\mu_f = \alpha_f * \mu_{pf} * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{fx} = 0.04286225$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\mu_{fy} = 0.04286225$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

$$\alpha_{se} ((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.11512199$$

$$\alpha_{se1} = \text{Max}(((A_{\text{conf}, \max 1} - A_{\text{noConf1}}) / A_{\text{conf}, \max 1}) * (A_{\text{conf}, \min 1} / A_{\text{conf}, \max 1}), 0) = 0.11081094$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf}, \min}$  and  $A_{\text{conf}, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf}, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf}, \min 1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf}, \max 1}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{\text{conf}, \max 2} - A_{\text{noConf2}}) / A_{\text{conf}, \max 2}) * (A_{\text{conf}, \min 2} / A_{\text{conf}, \max 2}), 0) = 0.12134906$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf}, \min}$  and  $A_{\text{conf}, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf}, \max 2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{\text{conf}, \min 2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf}, \max 2}$  by a length equal to half the clear spacing between internal hoops.

$A_{\text{noConf2}} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\mu_{psh, \min} * f_{ywe} = \text{Min}(\mu_{psh, x} * f_{ywe}, \mu_{psh, y} * f_{ywe}) = 0.87336895$$

Expression (5.4d) for  $psh_{min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.000721$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 0.87336895$   
 $psh1$  ((5.4d), TBDY) =  $Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.000721$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00  
s1 = 510.00  
s2 = 250.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888  
c = confinement factor = 1.03889

y1 = 0.0014252  
sh1 = 0.00456062  
ft1 = 455.1997  
fy1 = 379.3331  
su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb = 0.30798991  
su1 =  $0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 379.3331$

with Es1 =  $(Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$

y2 = 0.0014252  
sh2 = 0.00456062  
ft2 = 449.345  
fy2 = 374.4542  
su2 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.30798991  
su2 =  $0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 =  $(fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 374.4542$

with Es2 =  $(Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

yv = 0.0014252  
shv = 0.00456062  
ftv = 453.2097  
fyv = 377.6747  
suv = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$l_o/l_d, \min = l_b/l_d = 0.30798991$   
 $s_u = 0.4 \cdot e_{suv\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{suv\_nominal} = 0.08$ ,  
 considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $e_{suv\_nominal}$  and  $y_v$ ,  $sh_v, f_{tv}, f_{yv}$ , it is considered  
 characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1, f_{t1}, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{sv} = (f_{sj\_jacket} \cdot A_{sl\_mid\_jacket} + f_{sj\_mid} \cdot A_{sl\_mid\_core}) / A_{sl\_mid} = 377.6747$   
 with  $E_{sv} = (E_{sj\_jacket} \cdot A_{sl\_mid\_jacket} + E_{sj\_mid} \cdot A_{sl\_mid\_core}) / A_{sl\_mid} = 200000.00$   
 $1 = A_{sl\_ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.08977028$   
 $2 = A_{sl\_com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0456314$   
 $v = A_{sl\_mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08124101$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = A_{sl\_ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.11029209$   
 $2 = A_{sl\_com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.05606291$   
 $v = A_{sl\_mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.099813$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.2110448$   
 $Mu = MRc (4.14) = 8.0265E+008$   
 $u = su (4.1) = 9.7291088E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.30798991$

$l_b = 300.00$

$l_d = 974.0579$

Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot \text{Area}_{jacket} + f'_{c\_core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.68182$ , but  $f_c^{0.5} \leq$   
 8.3 MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 0.8418647$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 510.00$

$n = 24.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 653603.866$

Calculation of Shear Strength at edge 1,  $V_{r1} = 653603.866$

$V_{r1} = V_{CoI} ((10.3), ASCE 41-17) = knl \cdot V_{CoI0}$

$V_{CoI0} = 653603.866$

$knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77537$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 140237.117$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 61600.349$

$V_{sj1} = 61600.349$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{sj1}$  is multiplied by  $Col,j1 = 0.60$

$s/d = 0.85$

$V_{sj2} = 0.00$  is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{sj2}$  is multiplied by  $Col,j2 = 0.00$

$s/d = 1.59375$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 78636.768$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$

$s/d = 1.5625$

$V_f ((11-3)-(11.4), ACI 440) = 372533.843$

$f = 0.95$ , for fully-wrapped sections

$w_f/sf = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,

where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$

$b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$

$V_{Col0} = 653603.866$

$knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)  
Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 11.77482$   
 $V_u = 0.00051441$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.616$   
 $A_g = 300000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 140237.117$   
where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 61600.349$   
 $V_{sj1} = 61600.349$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{sj1}$  is multiplied by  $Col_{j1} = 0.60$   
 $s/d = 0.85$   
 $V_{sj2} = 0.00$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 510.00$   
 $V_{sj2}$  is multiplied by  $Col_{j2} = 0.00$   
 $s/d = 1.59375$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$   
 $V_{s,c1} = 78636.768$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col_{c1} = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col_{c2} = 0.00$   
 $s/d = 1.5625$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
where  $a$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
with  $f_u = 0.01$   
From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$   
 $b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjcs

#### Constant Properties

-----  
Knowledge Factor,  $\gamma = 0.90$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
#####  
Note: Especially for the calculation of moment strengths,  
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
Jacket  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
Existing Column  
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.03889  
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$   
-----

#### Stepwise Properties

-----  
At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = -0.00051441$   
EDGE -B-  
Shear Force,  $V_b = 0.00051441$   
BOTH EDGES  
Axial Force,  $F = -16273.616$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 5353.274$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1137.257$   
-Compression:  $A_{sl,com} = 2208.54$   
-Middle:  $A_{sl,mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.81868759$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 535097.371$   
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.0265E+008$

$M_{u1+} = 4.8921E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 8.0265E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.0265E+008$

$M_{u2+} = 4.8921E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 8.0265E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $M_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 8.9479397E-006$

$M_u = 4.8921E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

$\phi_c$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01186911$

we ((5.4c), TBDY) =  $a_{se} * \phi_{u,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.04377629$

where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$\phi_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = N L^* t \cos(\theta_1) = 1.016$



$$f_u, f = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase \ ((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.11512199$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 \ (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.12134906$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 0.87336895$$

Expression (5.4d) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 0.87336895$$

$$p_{sh1} \ ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \ (\text{Length of stirrups along Y}) = 2060.00$$

$$A_{stir1} \ (\text{stirrups area}) = 78.53982$$

$$p_{sh2} \ (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \ (\text{Length of stirrups along Y}) = 1468.00$$

$$A_{stir2} \ (\text{stirrups area}) = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 0.87336895$$

$$p_{sh1} \ ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$$

$$L_{stir1} \ (\text{Length of stirrups along X}) = 2060.00$$

$$A_{stir1} \ (\text{stirrups area}) = 78.53982$$

$$p_{sh2} \ ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \ (\text{Length of stirrups along X}) = 1468.00$$

$$A_{stir2} \ (\text{stirrups area}) = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 510.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0014252$$

$$sh1 = 0.00456062$$

$$ft1 = 449.345$$

$$fy1 = 374.4542$$

$$su1 = 0.00542681$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o / l_{ou,min} = l_b / d = 0.30798991$$

$$su1 = 0.4 * esu1_{nominal} \ ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 374.4542$   
 with  $Es1 = (Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$   
 $y2 = 0.0014252$   
 $sh2 = 0.00456062$   
 $ft2 = 455.1997$   
 $fy2 = 379.3331$   
 $su2 = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/lb,min = 0.30798991$   
 $su2 = 0.4 \cdot esu2\_nominal \cdot ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 379.3331$   
 with  $Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.0014252$   
 $shv = 0.00456062$   
 $ftv = 453.2097$   
 $fyv = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.30798991$   
 $suv = 0.4 \cdot esuv\_nominal \cdot ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 377.6747$   
 with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.02433675$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.04787748$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.04332854$

and confined core properties:

$b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.0276252$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.05434683$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.04918322$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.14216778$   
 $Mu = MRc (4.14) = 4.8921E+008$   
 $u = su (4.1) = 8.9479397E-006$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.30798991$   
 $lb = 300.00$   
 $ld = 974.0579$

Calculation of  $lb,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\gamma = 1$   
 $d_b = 16.66667$   
Mean strength value of all re-bars:  $f_y = 655.558$   
Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$

#### Calculation of $\mu_1$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.7291088E-006$$

$$\mu_u = 8.0265E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} \cdot \text{Max}(\mu_c, \mu_{cc}) = 0.01186911$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01186911$$

$$\mu_{cc} \text{ ((5.4c), TBDY) } = a_{se} \cdot \frac{f_{ywe}}{f_{ce}} + \text{Min}(f_x, f_y) = 0.04377629$$

where  $f = a_f \cdot p_f \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY) } = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int}) / A_{sec} = 0.11512199$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.11081094$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 0.87336895$

Expression (5.4d) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 0.87336895$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 455.1997$

$fy1 = 379.3331$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.30798991$

$su1 = 0.4 * esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered

characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 379.3331$

with  $Es1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0014252$

```

sh2 = 0.00456062
ft2 = 449.345
fy2 = 374.4542
su2 = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/lb,min = 0.30798991
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
    with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 374.4542
    with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
    yv = 0.0014252
    shv = 0.00456062
    ftv = 453.2097
    fyv = 377.6747
    suv = 0.00542681
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/lb = 0.30798991
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
    with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 377.6747
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.08977028
    2 = Asl,com/(b*d)*(fs2/fc) = 0.0456314
    v = Asl,mid/(b*d)*(fsv/fc) = 0.08124101
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 34.2833
cc (5A.5, TBDY) = 0.00238888
c = confinement factor = 1.03889
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.11029209
    2 = Asl,com/(b*d)*(fs2/fc) = 0.05606291
    v = Asl,mid/(b*d)*(fsv/fc) = 0.099813
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.2110448
Mu = MRc (4.14) = 8.0265E+008
u = su (4.1) = 9.7291088E-006

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.30798991
lb = 300.00
lb = 974.0579
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 16.66667
Mean strength value of all re-bars: fy = 655.558
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00

```

$s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 0.8418647$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 510.00$   
 $n = 24.00$

Calculation of  $\mu_2$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 8.9479397\text{E-}006$   
 $\mu = 4.8921\text{E+}008$

with full section properties:

$b = 750.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093001$   
 $N = 16273.616$   
 $f_c = 33.00$   
 $\alpha (5A.5, \text{TBDY}) = 0.002$   
 Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01186911$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\mu = 0.01186911$   
 $\mu (5.4c, \text{TBDY}) = \alpha * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$   
 where  $f = \alpha * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $\rho_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6),  $\rho_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_f = 0.015$

$\alpha_{se} ((5.4d), \text{TBDY}) = (\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.11081094$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 71100.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.12134906$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 0.87336895$

Expression (5.4d) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 0.87336895  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.000721$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 510.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0014252

sh1 = 0.00456062

ft1 = 449.345

fy1 = 374.4542

su1 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min =  $l_b/l_d = 0.30798991$

su1 =  $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 374.4542$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.0014252

sh2 = 0.00456062

ft2 = 455.1997

fy2 = 379.3331

su2 = 0.00542681

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with

$\text{Shear\_factor} = 1.00$   
 $\text{lo/lou,min} = \text{lb/lb,min} = 0.30798991$   
 $\text{su2} = 0.4 * \text{esu2\_nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $\text{esu2\_nominal} = 0.08$ ,  
 For calculation of  $\text{esu2\_nominal}$  and  $y_2, \text{sh2,ft2,fy2}$ , it is considered  
 characteristic value  $\text{fsy2} = \text{fs2}/1.2$ , from table 5.1, TBDY.  
 $y_1, \text{sh1,ft1,fy1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $\text{fs2} = (\text{fs,jacket} * \text{Asl,com,jacket} + \text{fs,core} * \text{Asl,com,core}) / \text{Asl,com} = 379.3331$   
 with  $\text{Es2} = (\text{Es,jacket} * \text{Asl,com,jacket} + \text{Es,core} * \text{Asl,com,core}) / \text{Asl,com} = 200000.00$   
 $y_v = 0.0014252$   
 $\text{shv} = 0.00456062$   
 $\text{ftv} = 453.2097$   
 $\text{fyv} = 377.6747$   
 $\text{suv} = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with  $\text{shear\_factor}$   
 and also multiplied by the  $\text{shear\_factor}$  according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $\text{lo/lou,min} = \text{lb}/\text{ld} = 0.30798991$   
 $\text{suv} = 0.4 * \text{esuv\_nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $\text{esuv\_nominal} = 0.08$ ,  
 considering characteristic value  $\text{fsyv} = \text{fsv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $\text{esuv\_nominal}$  and  $y_v, \text{shv,ftv,fyv}$ , it is considered  
 characteristic value  $\text{fsyv} = \text{fsv}/1.2$ , from table 5.1, TBDY.  
 $y_1, \text{sh1,ft1,fy1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $\text{fsv} = (\text{fs,jacket} * \text{Asl,mid,jacket} + \text{fs,mid} * \text{Asl,mid,core}) / \text{Asl,mid} = 377.6747$   
 with  $\text{Esv} = (\text{Es,jacket} * \text{Asl,mid,jacket} + \text{Es,mid} * \text{Asl,mid,core}) / \text{Asl,mid} = 200000.00$   
 $1 = \text{Asl,ten}/(\text{b} * \text{d}) * (\text{fs1}/\text{fc}) = 0.02433675$   
 $2 = \text{Asl,com}/(\text{b} * \text{d}) * (\text{fs2}/\text{fc}) = 0.04787748$   
 $v = \text{Asl,mid}/(\text{b} * \text{d}) * (\text{fsv}/\text{fc}) = 0.04332854$

and confined core properties:

$b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $\text{fcc} (5A.2, \text{TBDY}) = 34.2833$   
 $\text{cc} (5A.5, \text{TBDY}) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = \text{Asl,ten}/(\text{b} * \text{d}) * (\text{fs1}/\text{fc}) = 0.0276252$   
 $2 = \text{Asl,com}/(\text{b} * \text{d}) * (\text{fs2}/\text{fc}) = 0.05434683$   
 $v = \text{Asl,mid}/(\text{b} * \text{d}) * (\text{fsv}/\text{fc}) = 0.04918322$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$\text{su} (4.9) = 0.14216778$

$\text{Mu} = \text{MRc} (4.14) = 4.8921\text{E}+008$

$u = \text{su} (4.1) = 8.9479397\text{E}-006$

Calculation of ratio  $\text{lb}/\text{ld}$

Lap Length:  $\text{lb}/\text{ld} = 0.30798991$

$\text{lb} = 300.00$

$\text{ld} = 974.0579$

Calculation of  $\text{lb,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$\text{db} = 16.66667$

Mean strength value of all re-bars:  $\text{fy} = 655.558$

Mean concrete strength:  $\text{fc}' = (\text{fc}'_{\text{jacket}} * \text{Area}_{\text{jacket}} + \text{fc}'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$ , but  $\text{fc}'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$\text{cb} = 25.00$

$\text{Ktr} = 0.8418647$

$\text{Atr} = \text{Min}(\text{Atr}_x, \text{Atr}_y) = 257.6106$

where  $\text{Atr}_x, \text{Atr}_y$  are the sum of the area of all stirrup legs along X and Y local axis



s = Max(s\_external,s\_internal) = 510.00  
n = 24.00

#### Calculation of Mu2-

Calculation of ultimate curvature  $\kappa_u$  according to 4.1, Biskinis/Fardis 2013:

$\kappa_u = 9.7291088E-006$

$M_u = 8.0265E+008$

with full section properties:

b = 400.00

d = 707.00

d' = 43.00

$\nu = 0.00174378$

N = 16273.616

f<sub>c</sub> = 33.00

$\alpha_{co}$  (5A.5, TBDY) = 0.002

Final value of  $\kappa_u$ :  $\kappa_u^* = \text{shear\_factor} * \text{Max}(\kappa_u, \alpha_{co}) = 0.01186911$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\kappa_u = 0.01186911$

$\nu_{we}$  ((5.4c), TBDY) =  $\alpha_{se} * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04377629$

where  $f = \alpha_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 870.5244$

R = 40.00

Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.11512199$

$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.11081094$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 71100.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$\alpha_{se2} (>= \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.12134906$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 0.87336895$

Expression (5.4d) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 0.87336895$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  (5.4d) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 0.87336895$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.000721$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 510.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00238888$

$c$  = confinement factor = 1.03889

$y1 = 0.0014252$

$sh1 = 0.00456062$

$ft1 = 455.1997$

$fy1 = 379.3331$

$su1 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30798991$

$su1 = 0.4 \cdot esu1_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 379.3331$

with  $Es1 = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.0014252$

$sh2 = 0.00456062$

$ft2 = 449.345$

$fy2 = 374.4542$

$su2 = 0.00542681$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30798991$

$su2 = 0.4 \cdot esu2_{nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y2$ ,  $sh2$ ,  $ft2$ ,  $fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs_{jacket} \cdot A_{sl,com,jacket} + fs_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 374.4542$   
 with  $Es2 = (Es_{jacket} \cdot A_{sl,com,jacket} + Es_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $yv = 0.0014252$   
 $shv = 0.00456062$   
 $ftv = 453.2097$   
 $fyv = 377.6747$   
 $suv = 0.00542681$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.30798991$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} \cdot A_{sl,mid,jacket} + fs_{mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 377.6747$   
 with  $Esv = (Es_{jacket} \cdot A_{sl,mid,jacket} + Es_{mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (fs1/fc) = 0.08977028$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (fs2/fc) = 0.0456314$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (fsv/fc) = 0.08124101$   
 and confined core properties:  
 $b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 34.2833$   
 $cc (5A.5, TBDY) = 0.00238888$   
 $c = \text{confinement factor} = 1.03889$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (fs1/fc) = 0.11029209$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (fs2/fc) = 0.05606291$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (fsv/fc) = 0.099813$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.2110448$   
 $Mu = MRc (4.14) = 8.0265E+008$   
 $u = su (4.1) = 9.7291088E-006$   
 -----  
 Calculation of ratio  $lb/ld$   
 -----  
 Lap Length:  $lb/ld = 0.30798991$   
 $lb = 300.00$   
 $ld = 974.0579$   
 Calculation of  $lb,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $fc'^{0.5} \leq$   
 8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 0.8418647$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$   
 -----  
 -----  
 -----  
 -----

Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 653603.866$

Calculation of Shear Strength at edge 1,  $V_{r1} = 653603.866$

$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$

$V_{Col0} = 653603.866$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 140237.117$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 61600.349$

$V_{sj1} = 0.00$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{sj1}$  is multiplied by  $Col_{j1} = 0.00$

$s/d = 1.59375$

$V_{sj2} = 61600.349$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{sj2}$  is multiplied by  $Col_{j2} = 0.60$

$s/d = 0.85$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col_{c1} = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78636.768$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col_{c2} = 1.00$

$s/d = 0.56818182$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 372533.843$

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $a_i = 45^\circ$  and  $a_i = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$

$V_f = \min(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$

bw = 400.00

Calculation of Shear Strength at edge 2,  $V_{r2} = 653603.866$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$

$V_{Col0} = 653603.866$

$knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$ , but  $f_c'^{0.5} < = 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 4.00$

$\mu_u = 11.78144$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 140237.117$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 61600.349$

$V_{sj1} = 0.00$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{sj1}$  is multiplied by  $Col_{j1} = 0.00$

$s/d = 1.59375$

$V_{sj2} = 61600.349$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 510.00$

$V_{sj2}$  is multiplied by  $Col_{j2} = 0.60$

$s/d = 0.85$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78636.768$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col_{c1} = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78636.768$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col_{c2} = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), ACI 440) = 372533.843$

$f = 0.95$ , for fully-wrapped sections

$w_f / s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 838832.606$   
 $bw = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
Section Type: rcjcs

#### Constant Properties

Knowledge Factor,  $\gamma = 0.90$   
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_b = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 86052.109$   
Shear Force,  $V_2 = 7895.088$   
Shear Force,  $V_3 = -147.9095$   
Axial Force,  $F = -17072.715$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 5353.274$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $Asl_{ten} = 1137.257$   
 -Compression:  $Asl_{com} = 2208.54$   
 -Middle:  $Asl_{mid} = 2007.478$   
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $Asl_{ten,jacket} = 829.3805$   
 -Compression:  $Asl_{com,jacket} = 1746.726$   
 -Middle:  $Asl_{mid,jacket} = 1545.664$   
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $Asl_{ten,core} = 307.8761$   
 -Compression:  $Asl_{com,core} = 461.8141$   
 -Middle:  $Asl_{mid,core} = 461.8141$   
 Mean Diameter of Tension Reinforcement,  $DbL = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = u = 0.03090867$   
 $u = y + p = 0.03434296$

- Calculation of  $y$  -

$y = (My * Ls / 3) / Eleff = 0.00028423$  ((4.29), Biskinis Phd))  
 $My = 4.1188E+008$   
 $Ls = M/V$  (with  $Ls > 0.1 * L$  and  $Ls < 2 * L$ ) = 300.00  
 From table 10.5, ASCE 41\_17:  $Eleff = factor * Ec * Ig = 1.4491E+014$   
 $factor = 0.30$   
 $Ag = 440000.00$   
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$   
 $N = 17072.715$   
 $Ec * Ig = Ec_{jacket} * Ig_{jacket} + Ec_{core} * Ig_{core} = 4.8303E+014$

Calculation of Yielding Moment  $My$

Calculation of  $y$  and  $My$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$   
 web width,  $bw = 400.00$   
 flange thickness,  $t = 400.00$

$y = \min(y_{ten}, y_{com})$   
 $y_{ten} = 3.0743398E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \min(f_y, 1.25 * f_y * (lb/d)^{2/3}) = 350.6021$   
 $d = 707.00$   
 $y = 0.19348343$   
 $A = 0.01018759$   
 $B = 0.004498$   
 with  $pt = 0.00376294$   
 $pc = 0.00416509$   
 $pv = 0.00378591$   
 $N = 17072.715$   
 $b = 750.00$   
 $" = 0.06082037$   
 $y_{comp} = 1.6462519E-005$   
 with  $fc^* (12.3, (ACI 440)) = 33.48734$   
 $fc = 33.00$   
 $fl = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $Ag = 0.44$   
 $g = pt + pc + pv = 0.01009575$   
 $rc = 40.00$   
 $Ae/Ac = 0.31291181$   
 Effective FRP thickness,  $tf = NL * t * \cos(b1) = 1.016$

effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.19181501$   
 $A = 0.01002364$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.19279145 < t/d$

Calculation of ratio  $I_b/I_d$

Lap Length:  $I_d/I_{d,min} = 0.38498739$   
 $I_b = 300.00$   
 $I_d = 779.2463$   
 Calculation of  $I$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 524.4464$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 0.8418647$   
 $A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \max(s_{external}, s_{internal}) = 510.00$   
 $n = 24.00$

- Calculation of  $p$  -

From table 10-8:  $p = 0.03405873$

with:

- Columns controlled by inadequate development or splicing along the clear height because  $I_b/I_d < 1$   
 shear control ratio  $V_y E / V_{ColOE} = 0.81868759$   
 $d = d_{external} = 707.00$   
 $s = s_{external} = 0.00$   
 -  $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00376294$   
 jacket:  $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.000721$   
 $A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction  
 $L_{stir1} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction  
 $s_1 = 510.00$   
 core:  $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00067082$   
 $A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction  
 $L_{stir2} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction  
 $s_2 = 250.00$

The term  $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$  is implemented to account for FRP contribution  
 where  $f = 2 \cdot t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength  
 All these variables have already been given in Shear control ratio calculation.  
 For the normalisation  $f_s$  of jacket is used.

$NUD = 17072.715$   
 $A_g = 440000.00$   
 $f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section\_area = 27.68182$   
 $f_{yIE} = (f_{y,ext\_Long\_Reinf} \cdot Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 529.9972$   
 $f_{yIE} = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 502.0032$   
 $pI = Area_{Tot\_Long\_Rein} / (b \cdot d) = 0.01009575$   
 $b = 750.00$   
 $d = 707.00$   
 $f_{cE} = 27.68182$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1



At local axis: 3  
Integration Section: (b)

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