

# Detailed Member Calculations

**Units: N&mm**

**Regulation: ASCE 41-17**

## Calculation No. 1

column C1, Floor 1

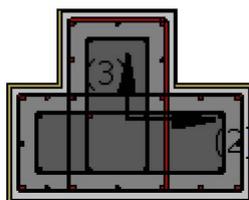
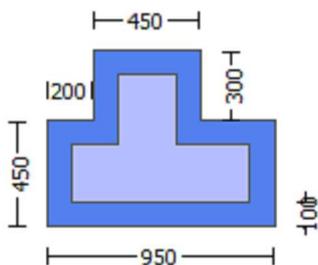
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Secondary 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  
New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
Concrete Elasticity,  $E_c = 26999.444$   
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  
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $E_{cc} = 200.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Secondary 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  
Inadequate Lap Length with  $l_o/l_{o,min} = l_b/l_d = 0.30$   
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,  $R = 40.00$

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Stepwise Properties  
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EDGE -A-  
Bending Moment,  $M_a = -2.4491E+007$   
Shear Force,  $V_a = -8039.906$   
EDGE -B-  
Bending Moment,  $M_b = 366061.641$   
Shear Force,  $V_b = 8039.906$   
BOTH EDGES  
Axial Force,  $F = -22426.397$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{l,ten} = 2682.92$   
-Compression:  $As_{l,com} = 1539.38$   
-Middle:  $As_{l,mid} = 2469.292$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.45455$   
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New component: From table 7-7, ASCE 41-17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 1.3519E+006$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoIO} = 1.3519E+006$   
 $V_{CoI} = 1.3519E+006$   
 $k_n = 1.00$   
displacement\_ductility\_demand = 0.01598361

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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$   
MPa ((22.5.3.1), ACI 318-14)  
 $M/Vd = 4.00$   
 $M_u = 2.4491E+007$   
 $V_u = 8039.906$   
 $d = 0.8 \cdot h = 760.00$   
 $N_u = 22426.397$   
 $A_g = 427500.00$   
From ((11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 1.0003E+006$   
where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 879645.943$   
 $V_{sj1} = 282743.339$  is calculated for section web jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.27777778$   
 $V_{sj2} = 596902.604$  is calculated for section flange jacket, with:  
 $d = 760.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.13157895$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 120637.158$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 500.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 120637.158$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 500.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 477918.239  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
In ((11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression,  
where  $\theta$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f(\theta, \alpha)$ , is implemented for every different fiber orientation  $\alpha_i$ ,  
as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
orientation 1:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$ , with:  
total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 907.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 1.1360E+006$   
 $b_w = 450.00$

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 =  $5.0561543E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.00316334$  ((4.29), Biskinis Phd))

$M_y = 8.7527E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3046.207

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.8095E+014$

factor = 0.30

$A_g = 562500.00$

Mean concrete strength:  $f'_c = (f'_{c\_jacket} * Area_{jacket} + f'_{c\_core} * Area_{core}) / Area_{section} = 33.00$

$N = 22426.397$

$E_c * I_g = E_{c\_jacket} * I_{g\_jacket} + E_{c\_core} * I_{g\_core} = 9.3651E+014$

Calculation of Yielding Moment  $M_y$

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

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

$y_{ten} = 2.3928489E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 311.2112$

$d = 907.00$

$y = 0.28302733$

$A = 0.01657149$

$B = 0.01009713$

with  $pt = 0.00657337$

$pc = 0.0037716$

$pv = 0.00604996$

$N = 22426.397$

$b = 450.00$

" = 0.04740904

$y_{comp} = 8.6876729E-006$

with  $f'_c$  (12.3, (ACI 440)) = 33.253

$f_c = 33.00$

$f_l = 0.43533893$

$b = b_{max} = 950.00$

$h = h_{max} = 750.00$

$A_g = 0.5625$

$g = pt + pc + pv = 0.01639493$

$rc = 40.00$

$A_e / A_c = 0.29742395$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.28134405$

$A = 0.01627101$

$B = 0.00992057$

with  $E_s = 200000.00$

Calculation of ratio  $l_b / l_d$

Inadequate Lap Length with  $l_b / l_d = 0.30$

End Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 2

column C1, Floor 1

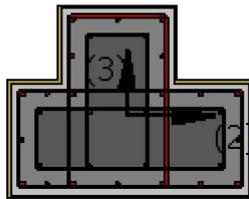
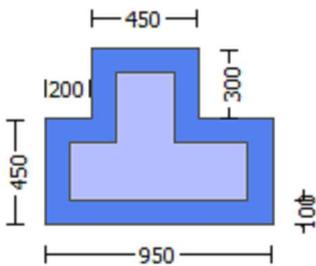
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta$ )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

#####

Max Height, Hmax = 750.00  
Min Height, Hmin = 450.00  
Max Width, Wmax = 950.00  
Min Width, Wmin = 450.00  
Eccentricity, Ecc = 200.00  
Jacket Thickness, tj = 100.00  
Cover Thickness, c = 25.00  
Mean Confinement Factor overall section = 1.02437  
Element Length, L = 3000.00  
Secondary 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  
Inadequate Lap Length with lo/lo,min = 0.30  
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

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Stepwise Properties  
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At local axis: 3  
EDGE -A-  
Shear Force, Va = -4.9265533E-005  
EDGE -B-  
Shear Force, Vb = 4.9265533E-005  
BOTH EDGES  
Axial Force, F = -20792.019  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Asc = 6691.592  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 2475.575  
-Compression: Asl,com = 1539.38  
-Middle: Asl,mid = 2676.637  
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Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.51791795$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 635124.647$   
with  
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 9.5269E+008$   
 $\mu_{u1+} = 9.5269E+008$ , 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  
 $\mu_{u1-} = 6.8428E+008$ , 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  
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 9.5269E+008$   
 $\mu_{u2+} = 9.5269E+008$ , 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  
 $\mu_{u2-} = 6.8428E+008$ , 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

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Calculation of  $\mu_{u1+}$   
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Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 8.7398457E-006$$

$$\mu = 9.5269E+008$$

with full section properties:

$$b = 950.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093808$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01211878$$

$$\omega_e (5.4c, \text{TBDY}) = a_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.04642716$$

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

$$\phi_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$$

$$b_{\text{max}} = 950.00$$

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

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$\phi_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$$

$$b_{\text{max}} = 950.00$$

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

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), \text{TBDY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53070105$$

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.

$A_{\text{conf,max2}} = 252164.00$  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.

$A_{\text{conf,min2}} = 111441.00$  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.

$AnoConf2 = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

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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 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$   
 $L_{stir1}$  (Length of stirrups along Y) = 2160.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$   
 $L_{stir2}$  (Length of stirrups along Y) = 1568.00  
 $A_{stir2}$  (stirrups area) = 50.26548

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 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$   
 $L_{stir1}$  (Length of stirrups along X) = 2560.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$   
 $L_{stir2}$  (Length of stirrups along X) = 1968.00  
 $A_{stir2}$  (stirrups area) = 50.26548

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 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

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

$lo/lou_{min} = lb/ld = 0.30$

$su1 = 0.4 * esu1_{nominal}$  ((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  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

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

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

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

$lo/lou_{min} = lb/lb_{min} = 0.30$

$su2 = 0.4 * esu2_{nominal}$  ((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  $fs2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 389.0139$

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

$yv = 0.00140044$

$shv = 0.0044814$

$ftv = 466.8167$

$fyv = 389.0139$

suv = 0.00512

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 = 0.30

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/d)^2/3), from 10.3.5, ASCE 41-17.

with fsv = (fsjacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04344945

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.02701806

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.04697834

and confined core properties:

b = 890.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04843381

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.03011747

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05236752

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.17139647

Mu = MRc (4.14) = 9.5269E+008

u = su (4.1) = 8.7398457E-006

-----  
Calculation of ratio lb/d

-----  
Inadequate Lap Length with lb/d = 0.30  
-----  
-----

-----  
Calculation of Mu1-  
-----  
-----

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 8.8144127E-006

Mu = 6.8428E+008  
-----

with full section properties:

b = 450.00

d = 707.00

d' = 43.00

v = 0.00198039

N = 20792.019

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01211878

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

From (5.4b), TBDY: cu = 0.01211878

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+ Min( fx, fy) = 0.04642716

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.03444474

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.28545185

$$\text{with Unconfined area} = ((b_{\max}-2R)^2 + (h_{\max}-2R)^2)/3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } ff,e = 881.8461$$

$$f_y = 0.03444474$$

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

$$af = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max}-2R)^2 + (h_{\max}-2R)^2)/3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } ff,e = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL*t*\text{Cos}(b1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\text{ase ((5.4d), TBDY)} = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.53070105$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{,min}*F_{ywe} = \text{Min}(psh_{,x}*F_{ywe}, psh_{,y}*F_{ywe}) = 2.48363$$

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)

$$psh_{,x}*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.48363$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00301593$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2160.00$$

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

$$psh2 \text{ (5.4d)} = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00056047$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1568.00$$

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

$$psh_{,y}*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.97078$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00357443$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$$

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

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00070345$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$$

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

Asec = 562500.00  
 s1 = 100.00  
 s2 = 250.00  
 fywe1 = 694.45  
 fywe2 = 694.45  
 fce = 33.00  
 From ((5.A.5), TBDY), TBDY: cc = 0.00224367  
 c = confinement factor = 1.02437  
 y1 = 0.00140044  
 sh1 = 0.0044814  
 ft1 = 466.8167  
 fy1 = 389.0139  
 su1 = 0.00512  
 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 = 0.30  
 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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139  
 with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00  
 y2 = 0.00140044  
 sh2 = 0.0044814  
 ft2 = 466.8167  
 fy2 = 389.0139  
 su2 = 0.00512  
 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 = 0.30  
 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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139  
 with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00  
 yv = 0.00140044  
 shv = 0.0044814  
 ftv = 466.8167  
 fyv = 389.0139  
 suv = 0.00512  
 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 = 0.30  
 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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139  
 with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00  
 1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.05703813  
 2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09172662  
 v = Asl,mid/(b\*d)\*(fsv/fc) = 0.0991765  
 and confined core properties:  
 b = 390.00  
 d = 677.00  
 d' = 13.00  
 fcc (5A.2, TBDY) = 33.80412  
 cc (5A.5, TBDY) = 0.00224367  
 c = confinement factor = 1.02437

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.06872961$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11052844$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.11950537$$

Case/Assumption: Unconfined full section - Steel rupture  
satisfies Eq. (4.3)

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

$$\text{su (4.9)} = 0.17840617$$

$$\text{Mu} = \text{MRc (4.14)} = 6.8428\text{E}+008$$

$$u = \text{su (4.1)} = 8.8144127\text{E}-006$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$

-----  
Calculation of  $\text{Mu}_{2+}$

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 8.7398457\text{E}-006$$

$$\text{Mu} = 9.5269\text{E}+008$$

-----  
with full section properties:

$$b = 950.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093808$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01211878$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.53070105$$

$$ase1 = \text{Max}(((Aconf,max1 - AnoConf1)/Aconf,max1) * (Aconf,min1/Aconf,max1), 0) = 0.53070105$$

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 = 464100.00 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 = 395025.00 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 = 174733.333 is the unconfined external core area which is equal to  $bi^2/6$  as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((Aconf,max2 - AnoConf2)/Aconf,max2) * (Aconf,min2/Aconf,max2), 0) = 0.53070105$$

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 = 252164.00 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 = 111441.00 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 = 112376.00 is the unconfined internal core area which is equal to  $bi^2/6$  as defined at (A.2).

$$psh,min * Fywe = \text{Min}(psh,x * Fywe, psh,y * Fywe) = 2.48363$$

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)

$$psh_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.48363$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00301593$$

$$Lstir1 \text{ (Length of stirrups along Y)} = 2160.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00056047$$

$$Lstir2 \text{ (Length of stirrups along Y)} = 1568.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$psh_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.97078$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00357443$$

$$Lstir1 \text{ (Length of stirrups along X)} = 2560.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$$

$$Lstir2 \text{ (Length of stirrups along X)} = 1968.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$Asec = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.45$$

$$fywe2 = 694.45$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

$$lo/lou,min = lb/ld = 0.30$$

$$su1 = 0.4 * esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$$

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.

$$\text{with } fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 389.0139$$

with  $E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 200000.00$   
 $y_2 = 0.00140044$   
 $sh_2 = 0.0044814$   
 $ft_2 = 466.8167$   
 $fy_2 = 389.0139$   
 $su_2 = 0.00512$   
 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  
 $l_0/l_{ou,min} = l_b/l_{b,min} = 0.30$   
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_2 = fs_2/1.2$ , 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  $fs_2 = (fs_{jacket} \cdot A_{s,com,jacket} + fs_{core} \cdot A_{s,com,core}) / A_{s,com} = 389.0139$   
 with  $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$   
 $y_v = 0.00140044$   
 $sh_v = 0.0044814$   
 $ft_v = 466.8167$   
 $fy_v = 389.0139$   
 $suv = 0.00512$   
 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  
 $l_0/l_{ou,min} = l_b/l_d = 0.30$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} \cdot A_{s,mid,jacket} + fs_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 389.0139$   
 with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.04344945$   
 $2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.02701806$   
 $v = A_{s,mid} / (b \cdot d) \cdot (fs_v / fc) = 0.04697834$

and confined core properties:

$b = 890.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.80412$   
 $cc (5A.5, TBDY) = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.04843381$   
 $2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.03011747$   
 $v = A_{s,mid} / (b \cdot d) \cdot (fs_v / fc) = 0.05236752$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_s, y_2$  - LHS eq.(4.5) is satisfied

---->

$su (4.9) = 0.17139647$   
 $\mu_u = MR_c (4.14) = 9.5269E+008$   
 $u = su (4.1) = 8.7398457E-006$

-----  
 Calculation of ratio  $l_b/l_d$

-----  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
 -----  
 -----

-----  
 Calculation of  $\mu_u$ -  
 -----  
 -----

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

$$\mu = 8.8144127E-006$$

$$\mu = 6.8428E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, \omega) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01211878$$

$$\omega (5.4c, TBDY) = \text{ase} * \text{sh, min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$$

$$b_{\text{max}} = 950.00$$

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

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$$

$$b_{\text{max}} = 950.00$$

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

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\text{ase ((5.4d), TBDY) = (ase1 * A_{\text{ext}} + \text{ase2} * A_{\text{int}}) / A_{\text{sec}} = 0.53070105$$

$$\text{ase1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$\text{ase2} (> = \text{ase1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53070105$$

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.

$A_{\text{conf,max2}} = 252164.00$  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.

$A_{\text{conf,min2}} = 111441.00$  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 = 112376.00 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 2.48363$$

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

$$psh_x * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 2.48363$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00301593$$

$$Lstir1 \text{ (Length of stirrups along Y)} = 2160.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00056047$$

$$Lstir2 \text{ (Length of stirrups along Y)} = 1568.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$psh_y * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 2.97078$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00357443$$

$$Lstir1 \text{ (Length of stirrups along X)} = 2560.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$$

$$Lstir2 \text{ (Length of stirrups along X)} = 1968.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$Asec = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

$$lo/lou_{min} = lb/ld = 0.30$$

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

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.

$$\text{with } fs1 = (fs_{jacket} * Asl_{ten,jacket} + fs_{core} * Asl_{ten,core}) / Asl_{ten} = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

$$lo/lou_{min} = lb/lb_{min} = 0.30$$

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

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.

$$\text{with } fs2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 389.0139$$

$$\text{with } Es2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$su_v = 0.00512$$

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 = 0.30

su\_v = 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 = 389.0139

with Es\_v = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.05703813

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09172662

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.0991765

and confined core properties:

b = 390.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.06872961

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.11052844

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.11950537

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.17840617

Mu = MRc (4.14) = 6.8428E+008

u = su (4.1) = 8.8144127E-006

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 1.2263E+006

Calculation of Shear Strength at edge 1, Vr1 = 1.2263E+006

Vr1 = VCol ((10.3), ASCE 41-17) = knl\*VCol0

VCol0 = 1.2263E+006

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 = 33.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 7.32046

Vu = 4.9265533E-005

d = 0.8\*h = 600.00

Nu = 20792.019

Ag = 337500.00

From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 936062.473

where:

Vs,jacket = Vs,j1 + Vs,j2 = 837764.743

Vs,j1 = 523602.964 is calculated for section web jacket, with:

d = 600.00

Av = 157079.633

fy = 555.56

$s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$   
 $V_{s,c1} = 98297.73$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.25$   
 $V_f((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \csc)\sin\alpha$  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:  $\alpha_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe}((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$   
 $b_w = 450.00$

-----  
 Calculation of Shear Strength at edge 2,  $V_{r2} = 1.2263E+006$   
 $V_{r2} = V_{Col}((10.3), ASCE 41-17) = knl \cdot V_{Col0}$   
 $V_{Col0} = 1.2263E+006$   
 $knl = 1$  (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).

-----  
 $\gamma_c = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 7.3142$   
 $V_u = 4.9265533E-005$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 20792.019$   
 $A_g = 337500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 936062.473$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 837764.743$   
 $V_{sj1} = 523602.964$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$s/d = 0.27777778$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

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

$s/d = 0.56818182$

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

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

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

$s/d = 1.25$

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

$f = 0.95$ , 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:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = NL * t / NoDir = 1.016$

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$

$b_w = 450.00$

-----  
-----  
End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 3

-----  
-----  
Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjtcs

Constant Properties

-----  
Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

```

New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$ 
Concrete Elasticity,  $E_c = 26999.444$ 
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
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$ 
#####
Max Height,  $H_{max} = 750.00$ 
Min Height,  $H_{min} = 450.00$ 
Max Width,  $W_{max} = 950.00$ 
Min Width,  $W_{min} = 450.00$ 
Eccentricity,  $Ecc = 200.00$ 
Jacket Thickness,  $t_j = 100.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.02437
Element Length,  $L = 3000.00$ 
Secondary 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
Inadequate Lap Length with  $l_o/l_{o,min} = 0.30$ 
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
-----
At local axis: 2
EDGE -A-
Shear Force,  $V_a = 0.00030591$ 
EDGE -B-
Shear Force,  $V_b = -0.00030591$ 
BOTH EDGES
Axial Force,  $F = -20792.019$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $A_{st} = 0.00$ 
-Compression:  $A_{sc} = 6691.592$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $A_{sl,ten} = 2682.92$ 
-Compression:  $A_{sl,com} = 1539.38$ 
-Middle:  $A_{sl,mid} = 2469.292$ 
-----
-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.55437584$ 
Member Controlled by Flexure ( $V_e/V_r < 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 860817.439$ 
with
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 1.2912E+009$ 
 $M_{u1+} = 1.2912E+009$ , 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

```

Mu1- = 8.6158E+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

Mpr2 = Max(Mu2+ , Mu2-) = 1.2912E+009

Mu2+ = 1.2912E+009, 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

Mu2- = 8.6158E+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 Mu1+  
-----

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

$\phi_u = 7.0548964E-006$

Mu = 1.2912E+009  
-----

with full section properties:

b = 450.00

d = 907.00

d' = 43.00

v = 0.0015437

N = 20792.019

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01211878$

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

From (5.4b), TBDY:  $\phi_{cu} = 0.01211878$

$\phi_{cc}$  ((5.4c), TBDY) =  $\text{ase} * \text{sh}_{,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

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

-----  
 $f_x = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$

$b_{\text{max}} = 950.00$

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

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$   
-----

$f_y = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$

$b_{\text{max}} = 950.00$

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

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$   
-----

R = 40.00

Effective FRP thickness,  $t_f = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\text{ase}$  ((5.4d), TBDY) =  $(\text{ase}_1 * A_{\text{ext}} + \text{ase}_2 * A_{\text{int}}) / A_{\text{sec}} = 0.53070105$

$\text{ase}_1 = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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 = 174733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - \text{AnoConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

AnoConf2 = 112376.00 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 2.48363$

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)

-----  
 $psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

-----  
 $psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

-----  
 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

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

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1_{nominal}$  ((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  $fs1 = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 389.0139$

with  $Es1 = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$$su_2 = 0.4 \cdot esu_{2\_nominal} ((5.5), TBDY) = 0.032$$

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  $fs_2 = fs_2/1.2$ , 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.

$$\text{with } fs_2 = (fs_{jacket} \cdot Asl_{,com,jacket} + fs_{core} \cdot Asl_{,com,core}) / Asl_{,com} = 389.0139$$

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

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$suv = 0.00512$$

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

$$lo/lo_{u,min} = lb/ld = 0.30$$

$$suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$$

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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_v = (fs_{jacket} \cdot Asl_{,mid,jacket} + fs_{mid} \cdot Asl_{,mid,core}) / Asl_{,mid} = 389.0139$$

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

$$1 = Asl_{,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.07748884$$

$$2 = Asl_{,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04446081$$

$$v = Asl_{,mid} / (b \cdot d) \cdot (fs_v / fc) = 0.07131877$$

and confined core properties:

$$b = 390.00$$

$$d = 877.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.80412$$

$$cc (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = Asl_{,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0924687$$

$$2 = Asl_{,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05305581$$

$$v = Asl_{,mid} / (b \cdot d) \cdot (fs_v / fc) = 0.08510586$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.19984886$$

$$Mu = MRc (4.14) = 1.2912E+009$$

$$u = su (4.1) = 7.0548964E-006$$

-----  
Calculation of ratio  $lb/ld$

-----  
Inadequate Lap Length with  $lb/ld = 0.30$   
-----  
-----

-----  
Calculation of  $Mu_1$ -  
-----  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 6.7307746E-006$$

$$Mu = 8.6158E+008$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01211878$$

$$\text{we ((5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} (\text{Length of stirrups along } Y) = 2160.00$$

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

$$p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

psh<sub>y</sub>\*Fywe = psh<sub>1</sub>\*Fywe<sub>1</sub>+ps<sub>2</sub>\*Fywe<sub>2</sub> = 2.97078  
psh<sub>1</sub> ((5.4d), TBDY) = Lstir<sub>1</sub>\*Astir<sub>1</sub>/(Asec\*s<sub>1</sub>) = 0.00357443  
Lstir<sub>1</sub> (Length of stirrups along X) = 2560.00  
Astir<sub>1</sub> (stirrups area) = 78.53982  
psh<sub>2</sub> ((5.4d), TBDY) = Lstir<sub>2</sub>\*Astir<sub>2</sub>/(Asec\*s<sub>2</sub>) = 0.00070345  
Lstir<sub>2</sub> (Length of stirrups along X) = 1968.00  
Astir<sub>2</sub> (stirrups area) = 50.26548

Asec = 562500.00  
s<sub>1</sub> = 100.00  
s<sub>2</sub> = 250.00

fywe<sub>1</sub> = 694.45  
fywe<sub>2</sub> = 694.45  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367  
c = confinement factor = 1.02437

y<sub>1</sub> = 0.00140044  
sh<sub>1</sub> = 0.0044814  
ft<sub>1</sub> = 466.8167  
fy<sub>1</sub> = 389.0139  
su<sub>1</sub> = 0.00512

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<sub>d</sub> = 0.30

su<sub>1</sub> = 0.4\*esu<sub>1\_nominal</sub> ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu<sub>1\_nominal</sub> = 0.08,

For calculation of esu<sub>1\_nominal</sub> and y<sub>1</sub>, sh<sub>1</sub>,ft<sub>1</sub>,fy<sub>1</sub>, it is considered  
characteristic value fsy<sub>1</sub> = fs<sub>1</sub>/1.2, from table 5.1, TBDY.

y<sub>1</sub>, sh<sub>1</sub>,ft<sub>1</sub>,fy<sub>1</sub>, are also multiplied by Min(1,1.25\*(lb/l<sub>d</sub>)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

with fs<sub>1</sub> = (fs<sub>jacket</sub>\*Asl<sub>ten,jacket</sub> + fs<sub>core</sub>\*Asl<sub>ten,core</sub>)/Asl<sub>ten</sub> = 389.0139

with Es<sub>1</sub> = (Es<sub>jacket</sub>\*Asl<sub>ten,jacket</sub> + Es<sub>core</sub>\*Asl<sub>ten,core</sub>)/Asl<sub>ten</sub> = 200000.00

y<sub>2</sub> = 0.00140044  
sh<sub>2</sub> = 0.0044814

ft<sub>2</sub> = 466.8167

fy<sub>2</sub> = 389.0139

su<sub>2</sub> = 0.00512

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<sub>b,min</sub> = 0.30

su<sub>2</sub> = 0.4\*esu<sub>2\_nominal</sub> ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu<sub>2\_nominal</sub> = 0.08,

For calculation of esu<sub>2\_nominal</sub> and y<sub>2</sub>, sh<sub>2</sub>,ft<sub>2</sub>,fy<sub>2</sub>, it is considered  
characteristic value fsy<sub>2</sub> = fs<sub>2</sub>/1.2, from table 5.1, TBDY.

y<sub>2</sub>, sh<sub>2</sub>,ft<sub>2</sub>,fy<sub>2</sub>, are also multiplied by Min(1,1.25\*(lb/l<sub>d</sub>)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

with fs<sub>2</sub> = (fs<sub>jacket</sub>\*Asl<sub>com,jacket</sub> + fs<sub>core</sub>\*Asl<sub>com,core</sub>)/Asl<sub>com</sub> = 389.0139

with Es<sub>2</sub> = (Es<sub>jacket</sub>\*Asl<sub>com,jacket</sub> + Es<sub>core</sub>\*Asl<sub>com,core</sub>)/Asl<sub>com</sub> = 200000.00

y<sub>v</sub> = 0.00140044  
sh<sub>v</sub> = 0.0044814

ft<sub>v</sub> = 466.8167

fy<sub>v</sub> = 389.0139

suv = 0.00512

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<sub>d</sub> = 0.30

suv = 0.4\*esuv<sub>nominal</sub> ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv<sub>nominal</sub> = 0.08,

considering characteristic value fsy<sub>v</sub> = fs<sub>v</sub>/1.2, from table 5.1, TBDY

For calculation of esuv<sub>nominal</sub> and y<sub>v</sub>, sh<sub>v</sub>,ft<sub>v</sub>,fy<sub>v</sub>, it is considered  
characteristic value fsy<sub>v</sub> = fs<sub>v</sub>/1.2, from table 5.1, TBDY.

y<sub>1</sub>, sh<sub>1</sub>,ft<sub>1</sub>,fy<sub>1</sub>, are also multiplied by Min(1,1.25\*(lb/l<sub>d</sub>)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

with fs<sub>v</sub> = (fs<sub>jacket</sub>\*Asl<sub>mid,jacket</sub> + fs<sub>mid</sub>\*Asl<sub>mid,core</sub>)/Asl<sub>mid</sub> = 389.0139

$$\text{with } E_{sv} = (E_{s,jacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$$

$$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.04446081$$

$$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.07748884$$

$$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07131877$$

and confined core properties:

$$b = 390.00$$

$$d = 877.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.80412$$

$$c_c (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.05305581$$

$$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0924687$$

$$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08510586$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16131742$$

$$M_u = M_{Rc} (4.14) = 8.6158E+008$$

$$u = s_u (4.1) = 6.7307746E-006$$

-----  
Calculation of ratio  $l_b / l_d$

-----  
Inadequate Lap Length with  $l_b / l_d = 0.30$

-----  
Calculation of  $M_{u2+}$

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 7.0548964E-006$$

$$M_u = 1.2912E+009$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} \cdot \text{Max}(c_u, c_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01211878$$

$$w_e ((5.4c), TBDY) = a_{se} \cdot s_{h,min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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)

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

hmax = 750.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

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

$ase((5.4d), \text{TBDY}) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.53070105$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (> ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1}((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}((5.4d), \text{TBDY}) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

$A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c =$  confinement factor = 1.02437

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

su1 = 0.00512

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 = 0.30

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\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.07748884

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.04446081

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.07131877

and confined core properties:

b = 390.00

d = 877.00

d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0924687

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.05305581

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.08510586

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.19984886

Mu = MRc (4.14) = 1.2912E+009

u = su (4.1) = 7.0548964E-006

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_2$

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

$$\mu = 6.7307746E-006$$

$$\mu_2 = 8.6158E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_c = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \mu_c = 0.01211878$$

$$\mu_{cc} \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((Aconf,max2 - AnoConf2)/Aconf,max2) * (Aconf,min2/Aconf,max2), 0) = 0.53070105$$

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 = 252164.00 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 = 111441.00 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 = 112376.00 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh,min * Fywe = \text{Min}(psh,x * Fywe, psh,y * Fywe) = 2.48363$$

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)

$$psh,x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.48363$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00301593$$

$$Lstir1 \text{ (Length of stirrups along Y)} = 2160.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00056047$$

$$Lstir2 \text{ (Length of stirrups along Y)} = 1568.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$psh,y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.97078$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00357443$$

$$Lstir1 \text{ (Length of stirrups along X)} = 2560.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$$

$$Lstir2 \text{ (Length of stirrups along X)} = 1968.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$Asec = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.45$$

$$fywe2 = 694.45$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

$$lo/lou,min = lb/l_d = 0.30$$

$$su1 = 0.4 * esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$$

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  $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs\_jacket * Asl,ten,jacket + fs\_core * Asl,ten,core) / Asl,ten = 389.0139$$

$$\text{with } Es1 = (Es\_jacket * Asl,ten,jacket + Es\_core * Asl,ten,core) / Asl,ten = 200000.00$$

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

$$lo/lou,min = lb/l_b,min = 0.30$$

$$su2 = 0.4 * esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $es_{u2\_nominal}$  and  $y_2$ ,  $sh_{2,ft2, fy2}$ , it is considered characteristic value  $fs_{y2} = fs_2/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_{1,ft1, fy1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = (fs_{jacket} \cdot Asl_{,com,jacket} + fs_{core} \cdot Asl_{,com,core}) / Asl_{,com} = 389.0139$

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

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$suv = 0.00512$

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

$lo/lo_{u,min} = lb/ld = 0.30$

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

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

considering characteristic value  $fs_{yv} = f_{sv}/1.2$ , 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  $fs_{yv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_{1,ft1, fy1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot Asl_{,mid,jacket} + f_{s,mid} \cdot Asl_{,mid,core}) / Asl_{,mid} = 389.0139$

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

$1 = Asl_{,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.04446081$

$2 = Asl_{,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.07748884$

$v = Asl_{,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07131877$

and confined core properties:

$b = 390.00$

$d = 877.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 33.80412$

$cc (5A.5, TBDY) = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$1 = Asl_{,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.05305581$

$2 = Asl_{,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0924687$

$v = Asl_{,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08510586$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.16131742$

$Mu = MRc (4.14) = 8.6158E+008$

$u = su (4.1) = 6.7307746E-006$

-----  
Calculation of ratio  $lb/ld$

-----  
Inadequate Lap Length with  $lb/ld = 0.30$   
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.5528E+006$   
-----

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.5528E+006$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{ColO}$

$V_{ColO} = 1.5528E+006$

$knl = 1$  (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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 57.90343$

$V_u = 0.00030591$   
 $d = 0.8 \cdot h = 760.00$   
 $N_u = 20792.019$   
 $A_g = 427500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 977392.20$   
 $V_{s,j1} = 314161.779$  is calculated for section web jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:  
 $d = 760.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.13157895$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 477918.239  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot)\sin\alpha$  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:  $\alpha = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 907.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 1.3051E+006$   
 $b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.5528E+006$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 1.5528E+006$   
 $k_{nl} = 1$  (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).

$\lambda = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M / Vd = 4.00$

Mu = 57.90455  
Vu = 0.00030591  
d = 0.8\*h = 760.00  
Nu = 20792.019  
Ag = 427500.00  
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 1.1114E+006

where:

Vs,jacket = Vs,j1 + Vs,j2 = 977392.20

Vs,j1 = 314161.779 is calculated for section web jacket, with:

d = 360.00  
Av = 157079.633  
fy = 555.56  
s = 100.00

Vs,j1 is multiplied by Col,j1 = 1.00

s/d = 0.27777778

Vs,j2 = 663230.422 is calculated for section flange jacket, with:

d = 760.00  
Av = 157079.633  
fy = 555.56  
s = 100.00

Vs,j2 is multiplied by Col,j2 = 1.00

s/d = 0.13157895

Vs,core = Vs,c1 + Vs,c2 = 134042.359

Vs,c1 = 0.00 is calculated for section web core, with:

d = 200.00  
Av = 100530.965  
fy = 555.56  
s = 250.00

Vs,c1 is multiplied by Col,c1 = 0.00

s/d = 1.25

Vs,c2 = 134042.359 is calculated for section flange core, with:

d = 600.00  
Av = 100530.965  
fy = 555.56  
s = 250.00

Vs,c2 is multiplied by Col,c2 = 1.00

s/d = 0.41666667

Vf ((11-3)-(11.4), ACI 440) = 477918.239

f = 0.95, for fully-wrapped sections

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

In (11.3)  $\sin^2 + \cos^2$  is replaced with  $(\cot^2 + \csc^2)\sin^2\alpha$  which is more a generalised expression,

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

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

orientation 1:  $\theta = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45,  $\theta$ )|, |Vf(-45,  $\theta$ )|), with:

total thickness per orientation,  $tf1 = NL*t/NoDir = 1.016$

dfv = d (figure 11.2, ACI 440) = 907.00

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 <= 1.3051E+006

bw = 450.00

-----  
End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At local axis: 2  
-----

Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $E_{cc} = 200.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary 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

Inadequate Lap Length with  $l_b/l_d = 0.30$

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

Bending Moment,  $M = -332414.048$

Shear Force,  $V_2 = -8039.906$

Shear Force,  $V_3 = 166.1154$

Axial Force,  $F = -22426.397$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{st,ten} = 2475.575$

-Compression:  $A_{st,com} = 1539.38$

-Middle:  $A_{st,mid} = 2676.637$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{st,ten,jacket} = 1859.823$

-Compression:  $A_{st,com,jacket} = 1231.504$

-Middle:  $A_{st,mid,jacket} = 2060.885$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{st,ten,core} = 615.7522$

-Compression:  $A_{st,com,core} = 307.8761$

-Middle:  $A_{st,mid,core} = 615.7522$

Mean Diameter of Tension Reinforcement,  $DbL = 16.72727$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0 \cdot u = 0.00243682$   
 $u = y + p = 0.00243682$

-----  
- Calculation of  $y$  -  
-----

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00243682$  ((4.29), Biskinis Phd))  
 $M_y = 6.7036E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 2001.103  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 1.8350E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$   
 $N = 22426.397$   
 $E_c \cdot I_g = E_{c,jacket} \cdot I_{g,jacket} + E_{c,core} \cdot I_{g,core} = 6.1166E+014$   
-----  
-----

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,  $b = 950.00$   
web width,  $b_w = 450.00$   
flange thickness,  $t = 450.00$   
-----

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 2.8727233E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 311.2112$   
 $d = 707.00$   
 $y = 0.23385327$   
 $A = 0.01007021$   
 $B = 0.00604627$   
with  $p_t = 0.00368581$   
 $p_c = 0.00229194$   
 $p_v = 0.00398517$   
 $N = 22426.397$   
 $b = 950.00$   
 $" = 0.06082037$   
 $y_{comp} = 1.3500408E-005$   
with  $f_c' (12.3, (ACI 440)) = 33.25688$   
 $f_c = 33.00$   
 $f_l = 0.43533893$   
 $b = b_{max} = 950.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.5625$   
 $g = p_t + p_c + p_v = 0.00996292$   
 $rc = 40.00$   
 $A_e / A_c = 0.30198841$   
Effective FRP thickness,  $t_f = N_L \cdot t \cdot \text{Cos}(b_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.23229127$   
 $A = 0.00988762$   
 $B = 0.00593898$   
with  $E_s = 200000.00$   
CONFIRMATION:  $y = 0.2329828 < t/d$   
-----  
-----

Calculation of ratio  $I_b / I_d$   
-----

Inadequate Lap Length with  $l_b/l_d = 0.30$

- 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  $V_{yE}/V_{CoIE} = 0.51791795$

$d = d_{\text{external}} = 707.00$

$s = s_{\text{external}} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f/bw \cdot (f_{fe}/f_s) = 0.00568407$

jacket:  $s_1 = A_{v1} \cdot L_{\text{stir1}} / (s_1 \cdot A_g) = 0.00301593$

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

$L_{\text{stir1}} = 2160.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot L_{\text{stir2}} / (s_2 \cdot A_g) = 0.00056047$

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

$L_{\text{stir2}} = 1568.00$ , 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.

$N_{UD} = 22426.397$

$A_g = 562500.00$

$f_{cE} = (f_{c_{\text{jacket}}} \cdot \text{Area}_{\text{jacket}} + f_{c_{\text{core}}} \cdot \text{Area}_{\text{core}}) / \text{section\_area} = 33.00$

$f_{yE} = (f_{y_{\text{ext\_Long\_Reinf}}} \cdot \text{Area}_{\text{ext\_Long\_Reinf}} + f_{y_{\text{int\_Long\_Reinf}}} \cdot \text{Area}_{\text{int\_Long\_Reinf}}) / \text{Area}_{\text{Tot\_Long\_Rein}} =$

$555.56$

$f_{yE} = (f_{y_{\text{ext\_Trans\_Reinf}}} \cdot s_1 + f_{y_{\text{int\_Trans\_Reinf}}} \cdot s_2) / (s_1 + s_2) = 555.56$

$p_l = \text{Area}_{\text{Tot\_Long\_Rein}} / (b \cdot d) = 0.00996292$

$b = 950.00$

$d = 707.00$

$f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (a)

### Calculation No. 3

column C1, Floor 1

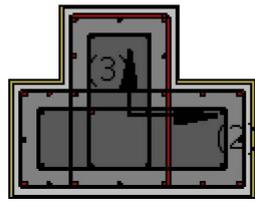
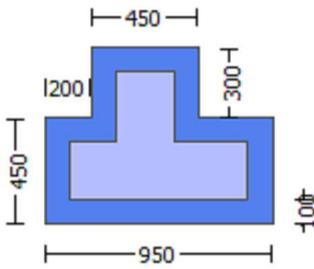
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Secondary 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

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $Ecc = 200.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary 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

Inadequate Lap Length with  $l_o/l_{o,min} = l_b/l_d = 0.30$

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,  $N_{Dir} = 1$   
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,  $M_a = -332414.048$   
Shear Force,  $V_a = 166.1154$   
EDGE -B-  
Bending Moment,  $M_b = -164532.52$   
Shear Force,  $V_b = -166.1154$   
BOTH EDGES  
Axial Force,  $F = -22426.397$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{s,ten} = 2475.575$   
-Compression:  $A_{s,com} = 1539.38$   
-Middle:  $A_{s,mid} = 2676.637$   
Mean Diameter of Tension Reinforcement,  $D_{bL,ten} = 16.72727$

-----  
New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 1.1019E+006$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI} = 1.1019E+006$   
 $V_{CoI} = 1.1019E+006$   
 $k_n = 1.00$   
displacement\_ductility\_demand = 0.00570038

-----  
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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 3.33517$   
 $M_u = 332414.048$   
 $V_u = 166.1154$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 22426.397$   
 $A_g = 337500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 842449.486$   
where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 753982.237$   
 $V_{s,j1} = 471238.898$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col_{j1} = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 282743.339$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col_{j2} = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 88467.249$   
 $V_{s,c1} = 88467.249$  is calculated for section web core, with:  
 $d = 440.00$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

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

$$s/d = 1.25$$

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

$f = 0.95$ , 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:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, a1)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$

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

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

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 896810.169$$

$$b_w = 450.00$$

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  $\theta = 1.3890801E-005$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00243682 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 6.7036E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 2001.103$$

$$\text{From table 10.5, ASCE 41-17: } E_{eff} = \text{factor} * E_c * I_g = 1.8350E+014$$

$$\text{factor} = 0.30$$

$$A_g = 562500.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$$

$$N = 22426.397$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 6.1166E+014$$

Calculation of Yielding Moment  $M_y$

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

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

$$\text{flange width, } b = 950.00$$

$$\text{web width, } b_w = 450.00$$

$$\text{flange thickness, } t = 450.00$$

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

$$y_{\text{ten}} = 2.8727233E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / d)^{2/3}) = 311.2112$$

$$d = 707.00$$

$$y = 0.23385327$$

$$A = 0.01007021$$

$$B = 0.00604627$$

$$\text{with } p_t = 0.00368581$$

pc = 0.00229194  
pv = 0.00398517  
N = 22426.397  
b = 950.00  
" = 0.06082037  
y\_comp = 1.3500408E-005  
with fc\* (12.3, (ACI 440)) = 33.25688  
fc = 33.00  
fl = 0.43533893  
b = bmax = 950.00  
h = hmax = 750.00  
Ag = 0.5625  
g = pt + pc + pv = 0.00996292  
rc = 40.00  
Ae/Ac = 0.30198841  
Effective FRP thickness, tf = NL\*t\*Cos(b1) = 1.016  
effective strain from (12.5) and (12.12), efe = 0.004  
fu = 0.01  
Ef = 64828.00  
Ec = 26999.444  
y = 0.23229127  
A = 0.00988762  
B = 0.00593898  
with Es = 200000.00  
CONFIRMATION: y = 0.2329828 < t/d

-----  
-----  
Calculation of ratio lb/ld

-----  
Inadequate Lap Length with lb/ld = 0.30

-----  
End Of Calculation of Shear Capacity for element: column JTC1 of floor 1  
At local axis: 3  
Integration Section: (a)  
-----

## Calculation No. 4

column C1, Floor 1

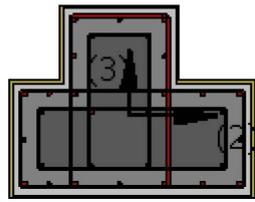
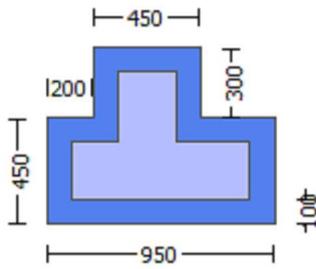
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( u)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $E_{cc} = 200.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.02437

Element Length,  $L = 3000.00$

Secondary 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

Inadequate Lap Length with  $l_o/l_{o,min} = 0.30$

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

At local axis: 3  
EDGE -A-  
Shear Force, Va = -4.9265533E-005  
EDGE -B-  
Shear Force, Vb = 4.9265533E-005  
BOTH EDGES  
Axial Force, F = -20792.019  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 6691.592  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 2475.575  
-Compression: Asl,com = 1539.38  
-Middle: Asl,mid = 2676.637

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.51791795$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 635124.647$   
with  
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 9.5269E+008$   
 $M_{u1+} = 9.5269E+008$ , 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  
 $M_{u1-} = 6.8428E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 9.5269E+008$   
 $M_{u2+} = 9.5269E+008$ , 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  
 $M_{u2-} = 6.8428E+008$ , 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:  
 $\phi_u = 8.7398457E-006$   
 $M_u = 9.5269E+008$

with full section properties:

$$b = 950.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093808$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01211878$$

$$\phi_u \text{ ((5.4c), TBDY)} = a_s e^* \phi_{s,\min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.04642716$$

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

$$\phi_x = 0.03444474$$

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

$$a_f = 0.28545185$$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 160566.667$

$$b_{\max} = 950.00$$

hmax = 750.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

fy = 0.03444474  
Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
af = 0.28545185  
with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$   
bmax = 950.00  
hmax = 750.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

R = 40.00  
Effective FRP thickness,  $tf = NL * t * \cos(b1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015

ase ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53070105$

ase1 =  $\text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

ase2 ( $\geq ase1$ ) =  $\text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

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)

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$   
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$   
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00  
s1 = 100.00

$s_2 = 250.00$   
 $fy_{we1} = 694.45$   
 $fy_{we2} = 694.45$   
 $f_{ce} = 33.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $y_1 = 0.00140044$   
 $sh_1 = 0.0044814$   
 $ft_1 = 466.8167$   
 $fy_1 = 389.0139$   
 $su_1 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/d = 0.30$   
 $su_1 = 0.4 * esu_1 \text{ nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_1 \text{ nominal} = 0.08$ ,  
 For calculation of  $esu_1 \text{ nominal}$  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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$   
 with  $Es_1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$   
 $y_2 = 0.00140044$   
 $sh_2 = 0.0044814$   
 $ft_2 = 466.8167$   
 $fy_2 = 389.0139$   
 $su_2 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/lb, \min = 0.30$   
 $su_2 = 0.4 * esu_2 \text{ nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_2 \text{ nominal} = 0.08$ ,  
 For calculation of  $esu_2 \text{ nominal}$  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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 389.0139$   
 with  $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.00140044$   
 $sh_v = 0.0044814$   
 $ft_v = 466.8167$   
 $fy_v = 389.0139$   
 $suv = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/d = 0.30$   
 $suv = 0.4 * esuv \text{ nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv \text{ nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv \text{ nominal}$  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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 389.0139$   
 with  $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / f_c) = 0.04344945$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / f_c) = 0.02701806$   
 $v = A_{sl,mid} / (b * d) * (fs_v / f_c) = 0.04697834$   
 and confined core properties:  
 $b = 890.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.80412$   
 $cc (5A.5, TBDY) = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / f_c) = 0.04843381$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / f_c) = 0.03011747$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05236752$$

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->

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

--->

$$s_u(4.9) = 0.17139647$$

$$M_u = M_{Rc}(4.14) = 9.5269E+008$$

$$u = s_u(4.1) = 8.7398457E-006$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $M_{u1}$ -

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

$$u = 8.8144127E-006$$

$$M_u = 6.8428E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \omega: \omega^* = \text{shear\_factor} \cdot \text{Max}(\omega, \omega_c) = 0.01211878$$

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

$$\text{From (5.4b), TB DY: } \omega_c = 0.01211878$$

$$\omega_{we}((5.4c), \text{TB DY}) = a_{se} \cdot \text{sh}_{, \min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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)

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se}((5.4d), \text{TB DY}) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int}) / A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) \cdot (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

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)

-----  
 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

-----  
 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

-----  
 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c$  = confinement factor = 1.02437

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1_{nominal}$  ((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  $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

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

$y2 = 0.00140044$

$sh_2 = 0.0044814$   
 $ft_2 = 466.8167$   
 $fy_2 = 389.0139$   
 $su_2 = 0.00512$   
 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  
 $lo/lo_{min} = lb/lb_{min} = 0.30$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 389.0139$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.00140044$   
 $shv = 0.0044814$   
 $ftv = 466.8167$   
 $fyv = 389.0139$   
 $suv = 0.00512$   
 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  
 $lo/lo_{min} = lb/ld = 0.30$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 389.0139$   
 with  $Esv = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.05703813$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.09172662$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.0991765$   
 and confined core properties:  
 $b = 390.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 33.80412$   
 $cc (5A.5, TBDY) = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.06872961$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.11052844$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.11950537$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.17840617$   
 $Mu = MRc (4.14) = 6.8428E+008$   
 $u = su (4.1) = 8.8144127E-006$

-----  
 Calculation of ratio  $lb/ld$   
 -----

Inadequate Lap Length with  $lb/ld = 0.30$   
 -----  
 -----

-----  
 Calculation of  $Mu_{2+}$   
 -----

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 8.7398457E-006$

Mu = 9.5269E+008

with full section properties:

b = 950.00

d = 707.00

d' = 43.00

v = 0.00093808

N = 20792.019

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01211878

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

From (5.4b), TBDY: cu = 0.01211878

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+ Min( fx, fy) = 0.04642716

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.03444474

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.28545185

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 160566.667

bmax = 950.00

hmax = 750.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

fy = 0.03444474

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.28545185

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 160566.667

bmax = 950.00

hmax = 750.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

R = 40.00

Effective FRP thickness, tf = NL\*t\*Cos(b1) = 1.016

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.53070105

ase1 = Max(((Aconf,max1-AnoConf1)/Aconf,max1)\*(Aconf,min1/Aconf,max1),0) = 0.53070105

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 = 464100.00 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 = 395025.00 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 = 174733.333 is the unconfined external core area which is equal to bi2/6 as defined at (A.2).

ase2 (>=ase1) = Max(((Aconf,max2-AnoConf2)/Aconf,max2)\*(Aconf,min2/Aconf,max2),0) = 0.53070105

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 = 252164.00 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 = 111441.00 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 = 112376.00 is the unconfined internal core area which is equal to bi2/6 as defined at (A.2).

psh,min\*Fywe = Min(psh,x\*Fywe, psh,y\*Fywe) = 2.48363

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

---

$$psh_x \cdot Fy_{we} = psh1 \cdot Fy_{we1} + ps2 \cdot Fy_{we2} = 2.48363$$
$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.00301593$$

Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982

$$psh2 \text{ (5.4d)} = Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00056047$$

Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

---

$$psh_y \cdot Fy_{we} = psh1 \cdot Fy_{we1} + ps2 \cdot Fy_{we2} = 2.97078$$
$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.00357443$$

Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00070345$$

Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

---

$$Asec = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 694.45$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

$$lo/lou_{min} = lb/ld = 0.30$$

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

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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

$$lo/lou_{min} = lb/lb_{min} = 0.30$$

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

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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 389.0139$$

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

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

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

$$l_0/l_{ou,min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

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

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv,nominal}$  and  $\gamma_v$ ,  $sh_v, ft_v, fy_v$ , it is considered

characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$$\gamma_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from } 10.3.5, \text{ ASCE } 41-17.$$

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 389.0139$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.04344945$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.02701806$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.04697834$$

and confined core properties:

$$b = 890.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.80412$$

$$c_c (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.04843381$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.03011747$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.05236752$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$$s_u (4.9) = 0.17139647$$

$$M_u = M_{Rc} (4.14) = 9.5269E+008$$

$$u = s_u (4.1) = 8.7398457E-006$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_2$ -

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

$$u = 8.8144127E-006$$

$$M_u = 6.8428E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, c_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.01211878$$

$$\text{we ((5.4c), TBDY) } = a_{se} * sh_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

fy = 0.03444474  
Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$   
af = 0.28545185  
with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 160566.667$   
bmax = 950.00  
hmax = 750.00  
From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00  
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015

ase ((5.4d), TBDY) =  $(ase_1 * A_{ext} + ase_2 * A_{int})/A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

$A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$$fy_{we2} = 694.45$$

$$f_{ce} = 33.00$$

From ((5.A.5), TBDY), TBDY:  $cc = 0.00224367$

$$c = \text{confinement factor} = 1.02437$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

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

$$lo/lo_{ou,min} = lb/ld = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$$

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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = (fs_{jacket} * Asl_{ten,jacket} + fs_{core} * Asl_{ten,core}) / Asl_{ten} = 389.0139$$

$$\text{with } Es_1 = (Es_{jacket} * Asl_{ten,jacket} + Es_{core} * Asl_{ten,core}) / Asl_{ten} = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

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

$$lo/lo_{ou,min} = lb/lb_{,min} = 0.30$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 389.0139$$

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

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$su_v = 0.00512$$

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

$$lo/lo_{ou,min} = lb/ld = 0.30$$

$$su_v = 0.4 * esu_{v,nominal} ((5.5), TBDY) = 0.032$$

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

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

For calculation of  $esu_{v,nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered  
characteristic value  $fsy_v = fs_v/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_v = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 389.0139$$

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

$$1 = Asl_{ten} / (b * d) * (fs_1 / f_c) = 0.05703813$$

$$2 = Asl_{com} / (b * d) * (fs_2 / f_c) = 0.09172662$$

$$v = Asl_{mid} / (b * d) * (fs_v / f_c) = 0.0991765$$

and confined core properties:

$$b = 390.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.80412$$

$$cc (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = Asl_{ten} / (b * d) * (fs_1 / f_c) = 0.06872961$$

$$2 = Asl_{com} / (b * d) * (fs_2 / f_c) = 0.11052844$$

$$v = Asl_{mid} / (b * d) * (fs_v / f_c) = 0.11950537$$

Case/Assumption: Unconfined full section - Steel rupture

satisfies Eq. (4.3)

--->

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

--->

$$\mu_u (4.9) = 0.17840617$$

$$\mu_u = M/R_c (4.14) = 6.8428E+008$$

$$u = \mu_u (4.1) = 8.8144127E-006$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.2263E+006$   
-----

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 1.2263E+006$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{ColO}$$

$$V_{ColO} = 1.2263E+006$$

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

-----  
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 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)

$$M/d = 4.00$$

$$\mu_u = 7.32046$$

$$V_u = 4.9265533E-005$$

$$d = 0.8 * h = 600.00$$

$$N_u = 20792.019$$

$$A_g = 337500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{sjacket} + V_{s,core} = 936062.473$$

where:

$$V_{sjacket} = V_{sj1} + V_{sj2} = 837764.743$$

$V_{sj1} = 523602.964$  is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{sj1}$  is multiplied by  $Col_{j1} = 1.00$

$$s/d = 0.16666667$$

$V_{sj2} = 314161.779$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{sj2}$  is multiplied by  $Col_{j2} = 1.00$

$$s/d = 0.27777778$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c1}$  is multiplied by  $Col_{c1} = 1.00$

$$s/d = 0.56818182$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c2}$  is multiplied by  $Col_{c2} = 0.00$

$$s/d = 1.25$$

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

$f = 0.95$ , 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  $V_f(\theta, a_i)$ , 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:  $\theta = b_1 + 90^\circ = 90.00$

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

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

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.2263E+006$

$V_{r2} = V_{Col}((10.3), \text{ASCE 41-17}) = k_{nl} * V_{Col0}$

$V_{Col0} = 1.2263E+006$

$k_{nl} = 1$  (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).

$\gamma_c = 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/d = 4.00$

$\mu_u = 7.3142$

$V_u = 4.9265533E-005$

$d = 0.8 * h = 600.00$

$N_u = 20792.019$

$A_g = 337500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 936062.473$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$

$V_{s,j1} = 523602.964$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $Col_{j1} = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $Col_{j2} = 1.00$

$s/d = 0.27777778$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col_{c1} = 1.00$

$s/d = 0.56818182$

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

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col_{c2} = 0.00$

s/d = 1.25

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 + cota)sinα which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(α), is implemented for every different fiber orientation ai, as well as for 2 crack directions, α = 45° and α = -45° to take into consideration the cyclic seismic loading.

orientation 1: α1 = b1 + 90° = 90.00

Vf = Min(|Vf(45, α1)|, |Vf(-45, α1)|), with:

total thickness per orientation, tf1 = NL\*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 <= 1.0304E+006

bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjtcs

Constant Properties

Knowledge Factor, K = 1.00

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

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, fc = fcm = 33.00

New material of Secondary Member: Steel Strength, fs = fsm = 555.56

Concrete Elasticity, Ec = 26999.444

Steel Elasticity, Es = 200000.00

Existing Column

New material of Secondary Member: Concrete Strength, fc = fcm = 33.00

New material of Secondary Member: Steel Strength, fs = fsm = 555.56

Concrete Elasticity, Ec = 26999.444

Steel Elasticity, Es = 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, fs = 1.25\*fsm = 694.45

Existing Column

New material: Steel Strength, fs = 1.25\*fsm = 694.45

#####

Max Height, Hmax = 750.00

Min Height, Hmin = 450.00

Max Width, Wmax = 950.00

Min Width, Wmin = 450.00

Eccentricity, Ecc = 200.00

Jacket Thickness, tj = 100.00

Cover Thickness, c = 25.00

Mean Confinement Factor overall section = 1.02437

Element Length, L = 3000.00

Secondary 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

Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$

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

-----  
At local axis: 2

EDGE -A-

Shear Force,  $V_a = 0.00030591$

EDGE -B-

Shear Force,  $V_b = -0.00030591$

BOTH EDGES

Axial Force,  $F = -20792.019$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 2682.92$

-Compression:  $As_{c,com} = 1539.38$

-Middle:  $As_{mid} = 2469.292$

-----  
-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.55437584$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 860817.439$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.2912E+009$

$Mu_{1+} = 1.2912E+009$ , 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

$Mu_{1-} = 8.6158E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.2912E+009$

$Mu_{2+} = 1.2912E+009$ , 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

$Mu_{2-} = 8.6158E+008$ , 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  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 7.0548964E-006$

$M_u = 1.2912E+009$

-----  
with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.019$

$f_c = 33.00$

$\phi_0$  (5A.5, TBDY) = 0.002

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$

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

From (5.4b), TBDY:  $c_u = 0.01211878$

$w_e$  ((5.4c), TBDY) =  $a_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

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

-----  
 $f_x = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $f_y = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $R = 40.00$

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), TBDY) =  $(a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$

$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$a_{se2} (> a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53070105$

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.

$A_{\text{conf,max2}} = 252164.00$  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.

$A_{\text{conf,min2}} = 111441.00$  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.

$A_{\text{noConf2}} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.97078$   
 $psh1 ((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00357443$   
 Lstir1 (Length of stirrups along X) = 2560.00  
 Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$   
 Lstir2 (Length of stirrups along X) = 1968.00  
 Astir2 (stirrups area) = 50.26548

Asec = 562500.00  
 s1 = 100.00  
 s2 = 250.00

fywe1 = 694.45  
 fywe2 = 694.45  
 fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367  
 c = confinement factor = 1.02437

y1 = 0.00140044  
 sh1 = 0.0044814  
 ft1 = 466.8167  
 fy1 = 389.0139  
 su1 = 0.00512

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

$lo/lou, min = lb/ld = 0.30$

$su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$

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 =  $(fs\_jacket * Asl, ten, jacket + fs\_core * Asl, ten, core) / Asl, ten = 389.0139$

with Es1 =  $(Es\_jacket * Asl, ten, jacket + Es\_core * Asl, ten, core) / Asl, ten = 200000.00$

y2 = 0.00140044  
 sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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

$lo/lou, min = lb/lb, min = 0.30$

$su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$

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 =  $(fs\_jacket * Asl, com, jacket + fs\_core * Asl, com, core) / Asl, com = 389.0139$

with Es2 =  $(Es\_jacket * Asl, com, jacket + Es\_core * Asl, com, core) / Asl, com = 200000.00$

yv = 0.00140044  
 shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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

$lo/lou, min = lb/ld = 0.30$

$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$

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 =  $(fs\_jacket * Asl, mid, jacket + fs\_mid * Asl, mid, core) / Asl, mid = 389.0139$

with Esv =  $(Es\_jacket * Asl, mid, jacket + Es\_mid * Asl, mid, core) / Asl, mid = 200000.00$

$1 = Asl, ten / (b * d) * (fs1 / fc) = 0.07748884$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.04446081$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07131877$$

and confined core properties:

$$b = 390.00$$

$$d = 877.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.80412$$

$$c_c (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0924687$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.05305581$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08510586$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.19984886$$

$$\mu_u = M_{Rc} (4.14) = 1.2912E+009$$

$$u = s_u (4.1) = 7.0548964E-006$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u1}$ -

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

$$u = 6.7307746E-006$$

$$\mu_u = 8.6158E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01211878$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00  
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

$A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c =$  confinement factor = 1.02437

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{d})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{d})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{d})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04446081

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07748884

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.07131877

and confined core properties:

b = 390.00

d = 877.00

d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.05305581

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0924687

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.08510586

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16131742

Mu = MRc (4.14) = 8.6158E+008

u = su (4.1) = 6.7307746E-006

-----  
Calculation of ratio lb/d

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{2+}$

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

$$\mu = 7.0548964E-006$$

$$\mu_u = 1.2912E+009$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.01211878$$

$$\mu_{ve} \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{, \text{min}} * f_{yve} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$$

$$b_{\text{max}} = 950.00$$

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

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$$

$$b_{\text{max}} = 950.00$$

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

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (> a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53070105$$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

-----  
 $A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

$Shear\_factor = 1.00$

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su_1 = 0.4 * esu1\_nominal$  ((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  $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

with  $Es_1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

$Shear\_factor = 1.00$

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$

$su_2 = 0.4 * esu2\_nominal$  ((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  $fs_2 = (fs_{jacket} \cdot A_{s1,com,jacket} + fs_{core} \cdot A_{s1,com,core}) / A_{s1,com} = 389.0139$

with  $Es_2 = (Es_{jacket} \cdot A_{s1,com,jacket} + Es_{core} \cdot A_{s1,com,core}) / A_{s1,com} = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$suv = 0.00512$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

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  $fsv = (fs_{jacket} \cdot A_{s,mid,jacket} + fs_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 389.0139$

with  $Esv = (Es_{jacket} \cdot A_{s,mid,jacket} + Es_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.07748884$

$2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04446081$

$v = A_{s,mid} / (b \cdot d) \cdot (fsv / fc) = 0.07131877$

and confined core properties:

$b = 390.00$

$d = 877.00$

$d' = 13.00$

$fcc$  (5A.2, TBDY) = 33.80412

$cc$  (5A.5, TBDY) = 0.00224367

$c$  = confinement factor = 1.02437

$1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0924687$

$2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05305581$

$v = A_{s,mid} / (b \cdot d) \cdot (fsv / fc) = 0.08510586$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su$  (4.9) = 0.19984886

$Mu = MRc$  (4.14) = 1.2912E+009

$u = su$  (4.1) = 7.0548964E-006

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $Mu_2$ -

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

$u = 6.7307746E-006$

$Mu = 8.6158E+008$

with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.019$

$fc = 33.00$

$co$  (5A.5, TBDY) = 0.002

Final value of  $cu$ :  $cu^* = \text{shear\_factor} \cdot \text{Max}(cu, cc) = 0.01211878$

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

From (5.4b), TBDY:  $c_u = 0.01211878$

$w_e$  ((5.4c), TBDY) =  $ase * sh_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

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

$f_x = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,e} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (\geq ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

psh1 ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367

c = confinement factor = 1.02437

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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 = 0.30

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 =  $(fs\_jacket * A_{sl,ten,jacket} + fs\_core * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

with Es1 =  $(Es\_jacket * A_{sl,ten,jacket} + Es\_core * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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 =  $(fs\_jacket * A_{sl,com,jacket} + fs\_core * A_{sl,com,core}) / A_{sl,com} = 389.0139$

with Es2 =  $(Es\_jacket * A_{sl,com,jacket} + Es\_core * A_{sl,com,core}) / A_{sl,com} = 200000.00$

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv =  $(fs\_jacket * A_{sl,mid,jacket} + fs\_mid * A_{sl,mid,core}) / A_{sl,mid} = 389.0139$

with Esv =  $(Es\_jacket * A_{sl,mid,jacket} + Es\_mid * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$

1 =  $A_{sl,ten} / (b * d) * (fs1 / fc) = 0.04446081$

2 =  $A_{sl,com} / (b * d) * (fs2 / fc) = 0.07748884$

v =  $A_{sl,mid} / (b * d) * (fsv / fc) = 0.07131877$

and confined core properties:

$$b = 390.00$$

$$d = 877.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.80412$$

$$cc (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05305581$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.0924687$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08510586$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16131742$$

$$\mu = MR_c (4.14) = 8.6158E+008$$

$$u = s_u (4.1) = 6.7307746E-006$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.5528E+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.5528E+006$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 1.5528E+006$$

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

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 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 57.90343$$

$$V_u = 0.00030591$$

$$d = 0.8 * h = 760.00$$

$$N_u = 20792.019$$

$$A_g = 427500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$$

where:

$$V_{s,jacket} = V_{sj1} + V_{sj2} = 977392.20$$

$V_{sj1} = 314161.779$  is calculated for section web jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{sj1}$  is multiplied by  $Col_{j1} = 1.00$

$$s/d = 0.27777778$$

$V_{sj2} = 663230.422$  is calculated for section flange jacket, with:

$$d = 760.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{sj2}$  is multiplied by  $Col_{j2} = 1.00$

$$s/d = 0.13157895$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 477918.239

$f = 0.95$ , 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:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 907.00

$f_{fe}$  ((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:  $V_s + V_f \leq 1.3051E+006$

$b_w = 450.00$

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 1.5528E+006$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$

$V_{Col0} = 1.5528E+006$

$k_{nl} = 1$  (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).

-----  
 $\rho = 1$  (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/d = 4.00$

$\mu_u = 57.90455$

$V_u = 0.00030591$

$d = 0.8 * h = 760.00$

$N_u = 20792.019$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$

where:

$V_{s,jacket} = V_{sj1} + V_{sj2} = 977392.20$

$V_{sj1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{sj1}$  is multiplied by  $Col,j1 = 1.00$

$s/d = 0.27777778$

$V_{sj2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{sj2}$  is multiplied by  $Col,j2 = 1.00$

$s/d = 0.13157895$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$

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

$d = 200.00$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.25$$

$V_{s,c2} = 134042.359$  is calculated for section flange core, with:

$$d = 600.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 0.41666667$$

$V_f$  ((11-3)-(11.4), ACI 440) = 477918.239

$f = 0.95$ , 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,  $tf1 = NL*t/NoDir = 1.016$

$dfv = d$  (figure 11.2, ACI 440) = 907.00

$ffe$  ((11-5), ACI 440) = 259.312

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440:  $V_s + V_f \leq 1.3051E+006$

$$bw = 450.00$$

-----  
-----  
End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 2

-----  
-----  
Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
At local axis: 3  
Integration Section: (a)  
Section Type: rcjtcs

Constant Properties

-----  
Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $Ecc = 200.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary 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  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
 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

-----  
 Bending Moment,  $M = -2.4491E+007$   
 Shear Force,  $V_2 = -8039.906$   
 Shear Force,  $V_3 = 166.1154$   
 Axial Force,  $F = -22426.397$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $As_{lt} = 0.00$   
 -Compression:  $As_{lc} = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten} = 2682.92$   
 -Compression:  $As_{l,com} = 1539.38$   
 -Middle:  $As_{l,mid} = 2469.292$   
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten,jacket} = 2375.044$   
 -Compression:  $As_{l,com,jacket} = 1231.504$   
 -Middle:  $As_{l,mid,jacket} = 1545.664$   
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten,core} = 307.8761$   
 -Compression:  $As_{l,com,core} = 307.8761$   
 -Middle:  $As_{l,mid,core} = 923.6282$   
 Mean Diameter of Tension Reinforcement,  $DbL = 17.45455$

-----  
 New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.00316334$   
 $u = y + p = 0.00316334$

-----  
 - Calculation of  $y$  -

-----  
 $y = (M_y * L_s / 3) / E_{eff} = 0.00316334$  ((4.29), Biskinis Phd))  
 $M_y = 8.7527E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3046.207  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.8095E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 22426.397$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.3651E+014$

-----  
 Calculation of Yielding Moment  $M_y$

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

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

$y_{ten} = 2.3928489E-006$   
 with  $((10.1), ASCE 41-17) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/l_d)^{2/3}) = 311.2112$   
 $d = 907.00$   
 $y = 0.28302733$   
 $A = 0.01657149$   
 $B = 0.01009713$   
 with  $pt = 0.00657337$   
 $pc = 0.0037716$   
 $pv = 0.00604996$   
 $N = 22426.397$   
 $b = 450.00$   
 $" = 0.04740904$

$y_{comp} = 8.6876729E-006$   
 with  $f_c^* (12.3, (ACI 440)) = 33.253$   
 $f_c = 33.00$   
 $f_l = 0.43533893$   
 $b = b_{max} = 950.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.5625$   
 $g = pt + pc + pv = 0.01639493$   
 $rc = 40.00$   
 $A_e/A_c = 0.29742395$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.28134405$   
 $A = 0.01627101$   
 $B = 0.00992057$   
 with  $E_s = 200000.00$

-----  
 Calculation of ratio  $l_b/l_d$   
 -----

Inadequate Lap Length with  $l_b/l_d = 0.30$   
 -----

- 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  $V_y E / V_{CoI} O E = 0.55437584$

$d = d_{external} = 907.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00638555$

jacket:  $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.00357443$

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

$L_{stir1} = 2560.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00070345$

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

$L_{stir2} = 1968.00$ , 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.

$NUD = 22426.397$

$A_g = 562500.00$

$f_c E = (f_c \cdot \text{Area}_{jacket} + f_c \cdot \text{Area}_{core}) / \text{section\_area} = 33.00$

$f_y E = (f_y \cdot \text{ext\_Long\_Reinf} \cdot \text{Area}_{ext\_Long\_Reinf} + f_y \cdot \text{int\_Long\_Reinf} \cdot \text{Area}_{int\_Long\_Reinf}) / \text{Area}_{Tot\_Long\_Rein} = 555.56$

$f_y E = (f_y \cdot \text{ext\_Trans\_Reinf} \cdot s_1 + f_y \cdot \text{int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$

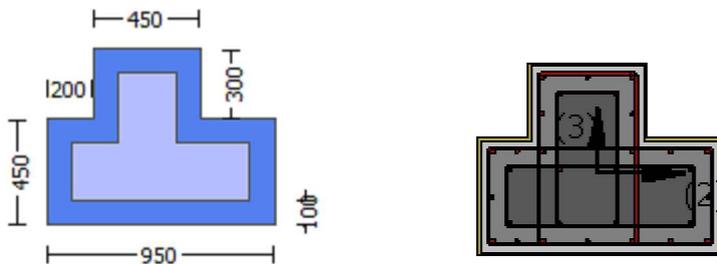
$p_l = \text{Area}_{Tot\_Long\_Rein} / (b \cdot d) = 0.01639493$

b = 450.00  
d = 907.00  
f<sub>cE</sub> = 33.00

End Of Calculation of Chord Rotation Capacity for element: column JTC1 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 VR<sub>d</sub>  
Edge: End  
Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1  
At local axis: 2  
Integration Section: (b)  
Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
New material of Secondary 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

New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
 Concrete Elasticity,  $E_c = 26999.444$   
 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  
 New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 450.00$   
 Max Width,  $W_{max} = 950.00$   
 Min Width,  $W_{min} = 450.00$   
 Eccentricity,  $Ecc = 200.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary 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  
 Inadequate Lap Length with  $l_o/l_{o,min} = l_b/l_d = 0.30$   
 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,  $M_a = -2.4491E+007$   
 Shear Force,  $V_a = -8039.906$   
 EDGE -B-  
 Bending Moment,  $M_b = 366061.641$   
 Shear Force,  $V_b = 8039.906$   
 BOTH EDGES  
 Axial Force,  $F = -22426.397$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $As_t = 0.00$   
 -Compression:  $As_c = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten} = 2682.92$   
 -Compression:  $As_{l,com} = 1539.38$   
 -Middle:  $As_{l,mid} = 2469.292$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.45455$   
 -----  
 -----

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 * V_n = 1.5679E+006$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{ColO} = 1.5679E+006$   
 $V_{Col} = 1.5679E+006$

knl = 1.00

displacement\_ductility\_demand = 0.04324142

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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 366061.641$

$V_u = 8039.906$

$d = 0.8 \cdot h = 760.00$

$N_u = 22426.397$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 1.0003\text{E}+006$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 879645.943$

$V_{s,j1} = 282743.339$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 596902.604$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 1.00$

$s/d = 0.13157895$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 120637.158$

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

$d = 200.00$

$A_v = 100530.965$

$f_y = 500.00$

$s = 250.00$

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

$s/d = 1.25$

$V_{s,c2} = 120637.158$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 500.00$

$s = 250.00$

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

$s/d = 0.41666667$

$V_f$  ((11-3)-(11.4), ACI 440) = 477918.239

$f = 0.95$ , for fully-wrapped sections

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

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

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

orientation 1:  $\theta = b1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 907.00

$f_{fe}$  ((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:  $V_s + V_f \leq 1.1360\text{E}+006$

$b_w = 450.00$

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  $\theta = 1.3471231E-005$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00031154$  ((4.29), Biskinis Phd)  
 $M_y = 8.7527E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.8095E+014$   
factor = 0.30  
 $A_g = 562500.00$   
Mean concrete strength:  $f'_c = (f'_{c\_jacket} * Area\_jacket + f'_{c\_core} * Area\_core) / Area\_section = 33.00$   
 $N = 22426.397$   
 $E_c * I_g = E_{c\_jacket} * I_{g\_jacket} + E_{c\_core} * I_{g\_core} = 9.3651E+014$   
-----  
-----

Calculation of Yielding Moment  $M_y$

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

-----  
 $y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 2.3928489E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 311.2112$   
 $d = 907.00$   
 $y = 0.28302733$   
 $A = 0.01657149$   
 $B = 0.01009713$   
with  $pt = 0.00657337$   
 $pc = 0.0037716$   
 $p_v = 0.00604996$   
 $N = 22426.397$   
 $b = 450.00$   
 $" = 0.04740904$   
 $y_{comp} = 8.6876729E-006$   
with  $f'_c$  (12.3, (ACI 440)) = 33.253  
 $f_c = 33.00$   
 $f_l = 0.43533893$   
 $b = b_{max} = 950.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.5625$   
 $g = pt + pc + p_v = 0.01639493$   
 $rc = 40.00$   
 $A_e / A_c = 0.29742395$   
Effective FRP thickness,  $t_f = N_L * t * \text{Cos}(\theta_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.28134405$   
 $A = 0.01627101$   
 $B = 0.00992057$   
with  $E_s = 200000.00$   
-----  
-----

Calculation of ratio  $l_b / l_d$

Inadequate Lap Length with  $l_b / l_d = 0.30$

End Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (b)

-----  
-----

## Calculation No. 6

column C1, Floor 1

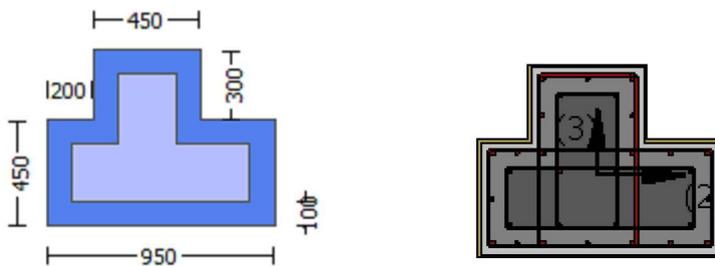
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $Ecc = 200.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.02437  
Element Length,  $L = 3000.00$   
Secondary 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  
Inadequate Lap Length with  $l_o/l_{o,min} = 0.30$   
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,  $V_a = -4.9265533E-005$   
EDGE -B-  
Shear Force,  $V_b = 4.9265533E-005$   
BOTH EDGES  
Axial Force,  $F = -20792.019$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 2475.575$   
-Compression:  $A_{st,com} = 1539.38$   
-Middle:  $A_{st,mid} = 2676.637$

-----  
Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.51791795$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 635124.647$   
with  
 $M_{pr1} = \text{Max}(\mu_{u1+} , \mu_{u1-}) = 9.5269E+008$   
 $\mu_{u1+} = 9.5269E+008$ , 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  
 $\mu_{u1-} = 6.8428E+008$ , 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  
 $M_{pr2} = \text{Max}(\mu_{u2+} , \mu_{u2-}) = 9.5269E+008$   
 $\mu_{u2+} = 9.5269E+008$ , 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  
 $\mu_{u2-} = 6.8428E+008$ , 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  $\mu_{u1+}$   
-----

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

u = 8.7398457E-006  
Mu = 9.5269E+008

with full section properties:

b = 950.00  
d = 707.00  
d' = 43.00  
v = 0.00093808  
N = 20792.019  
fc = 33.00  
co (5A.5, TBDY) = 0.002

Final value of cu:  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01211878$

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

From (5.4b), TBDY:  $cu = 0.01211878$

$w_e$  ((5.4c), TBDY) =  $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

where  $f = af * pf * ff_e / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.03444474$

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

$af = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A 4.4.3(6),  $pf = 2tf / bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff_e = 881.8461$

$f_y = 0.03444474$

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

$af = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A 4.4.3(6),  $pf = 2tf / bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff_e = 881.8461$

R = 40.00

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53070105$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $bi^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $bi^2/6$  as defined at (A.2).

$$psh_{min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 2.48363$$

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

$$psh_x * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 2.48363$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00301593$$

$$Lstir1 \text{ (Length of stirrups along Y)} = 2160.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00056047$$

$$Lstir2 \text{ (Length of stirrups along Y)} = 1568.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$psh_y * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 2.97078$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00357443$$

$$Lstir1 \text{ (Length of stirrups along X)} = 2560.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$$

$$Lstir2 \text{ (Length of stirrups along X)} = 1968.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$Asec = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

$$lo/lou_{min} = lb/ld = 0.30$$

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

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

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

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

$$\text{with } fs1 = (fs_{jacket} * Asl_{ten,jacket} + fs_{core} * Asl_{ten,core}) / Asl_{ten} = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

$$lo/lou_{min} = lb/lb_{min} = 0.30$$

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

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

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

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

$$\text{with } fs2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 389.0139$$

$$\text{with } Es2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$su_v = 0.00512$$

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fsjacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04344945

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.02701806

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.04697834

and confined core properties:

b = 890.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04843381

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.03011747

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05236752

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

v < vs,y2 - LHS eq.(4.5) is satisfied

---->

su (4.9) = 0.17139647

Mu = MRc (4.14) = 9.5269E+008

u = su (4.1) = 8.7398457E-006

-----  
Calculation of ratio lb/ld

-----  
Inadequate Lap Length with lb/ld = 0.30  
-----  
-----  
-----

-----  
Calculation of Mu1-  
-----  
-----  
-----

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 8.8144127E-006

Mu = 6.8428E+008  
-----

with full section properties:

b = 450.00

d = 707.00

d' = 43.00

v = 0.00198039

N = 20792.019

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01211878

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

From (5.4b), TBDY: cu = 0.01211878

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.04642716

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.03444474

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.28545185

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 160566.667

bmax = 950.00

hmax = 750.00

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $ff,e = 881.8461$

$fy = 0.03444474$

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

$af = 0.28545185$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff,e = 881.8461$

$R = 40.00$

Effective FRP thickness,  $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_u,f = 1055.00$

$E_f = 64828.00$

$u,f = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.53070105$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2$  ( $\geq ase1$ ) =  $\text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min}*F_{ywe} = \text{Min}(psh_x*F_{ywe}, psh_y*F_{ywe}) = 2.48363$

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)

$psh_x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.48363$

$psh1$  ((5.4d), TBDY) =  $L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$psh2$  (5.4d) =  $L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$psh_y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.97078$

$psh1$  ((5.4d), TBDY) =  $L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$psh2$  ((5.4d), TBDY) =  $L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

$A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

fywe1 = 694.45  
fywe2 = 694.45  
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00224367  
c = confinement factor = 1.02437

y1 = 0.00140044  
sh1 = 0.0044814  
ft1 = 466.8167  
fy1 = 389.0139  
su1 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044  
sh2 = 0.0044814  
ft2 = 466.8167  
fy2 = 389.0139  
su2 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044  
shv = 0.0044814  
ftv = 466.8167  
fyv = 389.0139  
suv = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.05703813

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09172662

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.0991765

and confined core properties:

b = 390.00  
d = 677.00  
d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.06872961

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.11052844

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.11950537

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) = 0.17840617  
 $M_u = M_{Rc}$  (4.14) = 6.8428E+008  
 $u = s_u$  (4.1) = 8.8144127E-006

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$

-----  
Calculation of  $M_{u2+}$

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 8.7398457E-006$   
 $M_u = 9.5269E+008$

-----  
with full section properties:

$b = 950.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093808$   
 $N = 20792.019$   
 $f_c = 33.00$   
 $\alpha$  (5A.5, TBDY) = 0.002

Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01211878$

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

From (5.4b), TBDY:  $\alpha = 0.01211878$

$\omega$  ((5.4c), TBDY) =  $\alpha * \text{sh\_min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

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

-----  
 $f_x = 0.03444474$

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

$\alpha_f = 0.28545185$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 160566.667$

$b_{\text{max}} = 950.00$

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

From EC8 A 4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $f_y = 0.03444474$

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

$\alpha_f = 0.28545185$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 160566.667$

$b_{\text{max}} = 950.00$

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

From EC8 A 4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $R = 40.00$

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) =  $(\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.53070105$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

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)

-----  
 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

-----  
 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

-----  
 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

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

$lo/lo_{u,min} = lb/ld = 0.30$

$su1 = 0.4 * esu1_{nominal}$  ((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  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

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

$y2 = 0.00140044$

$sh2 = 0.0044814$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 389.0139$$

$$\text{with } Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

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

$$lo/lou,min = lb/ld = 0.30$$

$$suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$$

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  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 389.0139$$

$$\text{with } Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.04344945$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.02701806$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.04697834$$

and confined core properties:

$$b = 890.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.80412$$

$$cc (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.04843381$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.03011747$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.05236752$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < vs,y2$  - LHS eq.(4.5) is satisfied

---->

$$su (4.9) = 0.17139647$$

$$Mu = MRc (4.14) = 9.5269E+008$$

$$u = su (4.1) = 8.7398457E-006$$

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.8144127E-006$$

$$Mu = 6.8428E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \alpha = 0.01211878$$

$$\alpha_w \text{ ((5.4c), TBDY) } = \alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$\alpha_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$$

$$b_{\text{max}} = 950.00$$

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

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.03444474$$

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

$$\alpha_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$$

$$b_{\text{max}} = 950.00$$

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

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY) } = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.53070105$$

$$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53070105$$

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.

$A_{\text{conf,max2}} = 252164.00$  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.

$A_{\text{conf,min2}} = 111441.00$  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.

$A_{\text{noConf2}} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\rho_{sh, \text{min}} * f_{ywe} = \text{Min}(\rho_{sh, x} * f_{ywe}, \rho_{sh, y} * f_{ywe}) = 2.48363$$

Expression (5.4d) for  $\rho_{sh, \text{min}} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without

earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.48363  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00301593  
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
psh2 (5.4d) = Lstir2\*Astir2/(Asec\*s2) = 0.00056047  
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00357443  
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00070345  
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367

c = confinement factor = 1.02437

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

$$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$$

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  $Min(1,1.25*(lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs\_jacket * Asl\_mid\_jacket + fs\_mid * Asl\_mid\_core) / Asl\_mid = 389.0139$$

$$\text{with } Esv = (Es\_jacket * Asl\_mid\_jacket + Es\_mid * Asl\_mid\_core) / Asl\_mid = 200000.00$$

$$1 = Asl\_ten / (b * d) * (fs1 / fc) = 0.05703813$$

$$2 = Asl\_com / (b * d) * (fs2 / fc) = 0.09172662$$

$$v = Asl\_mid / (b * d) * (fsv / fc) = 0.0991765$$

and confined core properties:

$$b = 390.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.80412$$

$$cc (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = Asl\_ten / (b * d) * (fs1 / fc) = 0.06872961$$

$$2 = Asl\_com / (b * d) * (fs2 / fc) = 0.11052844$$

$$v = Asl\_mid / (b * d) * (fsv / fc) = 0.11950537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$  - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.17840617$$

$$Mu = MRc (4.14) = 6.8428E+008$$

$$u = su (4.1) = 8.8144127E-006$$

Calculation of ratio  $lb/l_d$

Inadequate Lap Length with  $lb/l_d = 0.30$

Calculation of Shear Strength  $Vr = Min(Vr1, Vr2) = 1.2263E+006$

Calculation of Shear Strength at edge 1,  $Vr1 = 1.2263E+006$

$$Vr1 = VCol ((10.3), ASCE 41-17) = knl * VCol0$$

$$VCol0 = 1.2263E+006$$

$$knl = 1 \text{ (zero step-static loading)}$$

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).

$$= 1 \text{ (normal-weight concrete)}$$

Mean concrete strength:  $fc' = (fc'_jacket * Area\_jacket + fc'_core * Area\_core) / Area\_section = 33.00$ , but  $fc'^{0.5} <= 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/d = 4.00$$

$$Mu = 7.32046$$

$$Vu = 4.9265533E-005$$

$$d = 0.8 * h = 600.00$$

$$Nu = 20792.019$$

$$Ag = 337500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } Vs = Vs\_jacket + Vs\_core = 936062.473$$

where:

$$Vs\_jacket = Vs\_j1 + Vs\_j2 = 837764.743$$

$Vs\_j1 = 523602.964$  is calculated for section web jacket, with:

$$d = 600.00$$

$$Av = 157079.633$$

$$fy = 555.56$$

$$s = 100.00$$

$Vs\_j1$  is multiplied by  $Col\_j1 = 1.00$

$$s/d = 0.16666667$$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.27777778$$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.25$$

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

$f = 0.95$ , 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  $V_f(\theta, a_i)$ , 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:  $\theta = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (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:  $V_s + V_f \leq 1.0304E+006$

$$b_w = 450.00$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.2263E+006$

$V_{r2} = V_{Col}((10.3), ASCE 41-17) = knl \cdot V_{ColO}$

$$V_{ColO} = 1.2263E+006$$

$knl = 1$  (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).

$\lambda = 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 7.3142$$

$$V_u = 4.9265533E-005$$

$$d = 0.8 \cdot h = 600.00$$

$$N_u = 20792.019$$

$$A_g = 337500.00$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 936062.473$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$$

$V_{s,j1} = 523602.964$  is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$$s/d = 0.16666667$$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.27777778$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.25$$

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

$f = 0.95$ , 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  $\theta$  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:  $\theta = b1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|), \text{ with:}$$

total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$

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

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

$$E_f = 64828.00$$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$

$$b_w = 450.00$$

-----  
End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 3

-----  
Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjtcs

Constant Properties

-----  
Knowledge Factor,  $\phi = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $Ecc = 200.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.02437  
Element Length,  $L = 3000.00$   
Secondary 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  
Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$   
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  
-----

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = 0.00030591$   
EDGE -B-  
Shear Force,  $V_b = -0.00030591$   
BOTH EDGES  
Axial Force,  $F = -20792.019$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 2682.92$   
-Compression:  $A_{sl,com} = 1539.38$   
-Middle:  $A_{sl,mid} = 2469.292$

-----  
-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.55437584$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 860817.439$   
with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.2912E+009$   
 $M_{u1+} = 1.2912E+009$ , 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  
 $M_{u1-} = 8.6158E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.2912E+009$

Mu2+ = 1.2912E+009, 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

Mu2- = 8.6158E+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 Mu1+  
-----

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

$$\mu = 7.0548964E-006$$

$$Mu = 1.2912E+009$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01211878$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e^* s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53070105$$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$$

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)

---

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2160.00$$

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

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1568.00$$

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

---

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$$

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

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$$

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

---

$$A_{sec} = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.30$$

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

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

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

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

$$\text{with } fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$$

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

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

For calculation of  $esu2_{nominal}$  and  $y2, sh2, ft2, fy2$ , it is considered

characteristic value  $f_{s2} = f_{s2}/1.2$ , 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  $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 389.0139$

with  $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$suv = 0.00512$

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

$l_o/l_{o,min} = l_b/l_d = 0.30$

$suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

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

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered

characteristic value  $f_{sv} = f_{sv}/1.2$ , 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  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 389.0139$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.07748884$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.04446081$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07131877$

and confined core properties:

$b = 390.00$

$d = 877.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 33.80412$

$cc (5A.5, TBDY) = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0924687$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.05305581$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08510586$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.19984886$

$Mu = MRc (4.14) = 1.2912E+009$

$u = su (4.1) = 7.0548964E-006$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
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-----  
Calculation of  $Mu_1$ -  
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-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 6.7307746E-006$

$Mu = 8.6158E+008$

-----  
with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.019$

$f_c = 33.00$

$co (5A.5, TBDY) = 0.002$

Final value of  $cu$ :  $cu^* = \text{shear\_factor} \cdot \text{Max}(cu, cc) = 0.01211878$

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

From (5.4b), TBDY:  $c_u = 0.01211878$

where ((5.4c), TBDY) =  $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

where  $f = af * pf * ff_e / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.03444474$

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

$af = 0.28545185$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf / bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff_e = 881.8461$

-----  
 $f_y = 0.03444474$

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

$af = 0.28545185$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf / bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff_e = 881.8461$

-----  
 $R = 40.00$

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53070105$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2$  ( $\geq ase1$ ) =  $\text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

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)

-----  
 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

psh<sub>y</sub>\*Fywe = psh<sub>1</sub>\*Fywe<sub>1</sub>+ps<sub>2</sub>\*Fywe<sub>2</sub> = 2.97078  
psh<sub>1</sub> ((5.4d), TBDY) = Lstir<sub>1</sub>\*Astir<sub>1</sub>/(Asec\*s<sub>1</sub>) = 0.00357443  
Lstir<sub>1</sub> (Length of stirrups along X) = 2560.00  
Astir<sub>1</sub> (stirrups area) = 78.53982  
psh<sub>2</sub> ((5.4d), TBDY) = Lstir<sub>2</sub>\*Astir<sub>2</sub>/(Asec\*s<sub>2</sub>) = 0.00070345  
Lstir<sub>2</sub> (Length of stirrups along X) = 1968.00  
Astir<sub>2</sub> (stirrups area) = 50.26548

Asec = 562500.00

s<sub>1</sub> = 100.00

s<sub>2</sub> = 250.00

fywe<sub>1</sub> = 694.45

fywe<sub>2</sub> = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367

c = confinement factor = 1.02437

y<sub>1</sub> = 0.00140044

sh<sub>1</sub> = 0.0044814

ft<sub>1</sub> = 466.8167

fy<sub>1</sub> = 389.0139

su<sub>1</sub> = 0.00512

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 = 0.30

su<sub>1</sub> = 0.4\*esu<sub>1\_nominal</sub> ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu<sub>1\_nominal</sub> = 0.08,

For calculation of esu<sub>1\_nominal</sub> and y<sub>1</sub>, sh<sub>1</sub>,ft<sub>1</sub>,fy<sub>1</sub>, it is considered  
characteristic value fsy<sub>1</sub> = fs<sub>1</sub>/1.2, from table 5.1, TBDY.

y<sub>1</sub>, sh<sub>1</sub>,ft<sub>1</sub>,fy<sub>1</sub>, are also multiplied by Min(1,1.25\*(lb/d)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

with fs<sub>1</sub> = (fs<sub>jacket</sub>\*Asl<sub>ten,jacket</sub> + fs<sub>core</sub>\*Asl<sub>ten,core</sub>)/Asl<sub>ten</sub> = 389.0139

with Es<sub>1</sub> = (Es<sub>jacket</sub>\*Asl<sub>ten,jacket</sub> + Es<sub>core</sub>\*Asl<sub>ten,core</sub>)/Asl<sub>ten</sub> = 200000.00

y<sub>2</sub> = 0.00140044

sh<sub>2</sub> = 0.0044814

ft<sub>2</sub> = 466.8167

fy<sub>2</sub> = 389.0139

su<sub>2</sub> = 0.00512

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 = 0.30

su<sub>2</sub> = 0.4\*esu<sub>2\_nominal</sub> ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu<sub>2\_nominal</sub> = 0.08,

For calculation of esu<sub>2\_nominal</sub> and y<sub>2</sub>, sh<sub>2</sub>,ft<sub>2</sub>,fy<sub>2</sub>, it is considered  
characteristic value fsy<sub>2</sub> = fs<sub>2</sub>/1.2, from table 5.1, TBDY.

y<sub>2</sub>, sh<sub>2</sub>,ft<sub>2</sub>,fy<sub>2</sub>, are also multiplied by Min(1,1.25\*(lb/d)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

with fs<sub>2</sub> = (fs<sub>jacket</sub>\*Asl<sub>com,jacket</sub> + fs<sub>core</sub>\*Asl<sub>com,core</sub>)/Asl<sub>com</sub> = 389.0139

with Es<sub>2</sub> = (Es<sub>jacket</sub>\*Asl<sub>com,jacket</sub> + Es<sub>core</sub>\*Asl<sub>com,core</sub>)/Asl<sub>com</sub> = 200000.00

y<sub>v</sub> = 0.00140044

sh<sub>v</sub> = 0.0044814

ft<sub>v</sub> = 466.8167

fy<sub>v</sub> = 389.0139

suv = 0.00512

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 = 0.30

suv = 0.4\*esuv<sub>nominal</sub> ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv<sub>nominal</sub> = 0.08,

considering characteristic value fsy<sub>v</sub> = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv<sub>nominal</sub> and y<sub>v</sub>, sh<sub>v</sub>,ft<sub>v</sub>,fy<sub>v</sub>, it is considered  
characteristic value fsy<sub>v</sub> = fsv/1.2, from table 5.1, TBDY.

y<sub>1</sub>, sh<sub>1</sub>,ft<sub>1</sub>,fy<sub>1</sub>, are also multiplied by Min(1,1.25\*(lb/d)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

with fsv = (fs<sub>jacket</sub>\*Asl<sub>mid,jacket</sub> + fs<sub>mid</sub>\*Asl<sub>mid,core</sub>)/Asl<sub>mid</sub> = 389.0139

with Es<sub>v</sub> = (Es<sub>jacket</sub>\*Asl<sub>mid,jacket</sub> + Es<sub>mid</sub>\*Asl<sub>mid,core</sub>)/Asl<sub>mid</sub> = 200000.00

1 = Asl<sub>ten</sub>/(b\*d)\*(fs<sub>1</sub>/fc) = 0.04446081

2 = Asl<sub>com</sub>/(b\*d)\*(fs<sub>2</sub>/fc) = 0.07748884

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07131877$$

and confined core properties:

$$b = 390.00$$

$$d = 877.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.80412$$

$$c_c (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05305581$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.0924687$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08510586$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16131742$$

$$M_u = M_{Rc} (4.14) = 8.6158E+008$$

$$u = s_u (4.1) = 6.7307746E-006$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$

-----  
Calculation of  $M_{u2+}$

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

$$u = 7.0548964E-006$$

$$M_u = 1.2912E+009$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01211878$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase \text{ ((5.4d), TBDY)} = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

$A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c =$  confinement factor = 1.02437

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.07748884

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.04446081

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.07131877

and confined core properties:

b = 390.00

d = 877.00

d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0924687

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.05305581

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.08510586

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.19984886

Mu = MRc (4.14) = 1.2912E+009

u = su (4.1) = 7.0548964E-006

-----  
Calculation of ratio lb/d  
-----

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_2$ -

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

$$\mu = 6.7307746E-006$$

$$\mu = 8.6158E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu = \text{shear\_factor} * \text{Max}(\mu_c, \mu_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \mu_c = 0.01211878$$

$$\mu_c \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

-----  
 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

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

$\text{Shear\_factor} = 1.00$

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1\_nominal$  ((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  $fs1 = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 389.0139$

with  $Es1 = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

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

$\text{Shear\_factor} = 1.00$

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$su2 = 0.4 * esu2\_nominal$  ((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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 389.0139$   
 with  $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$   
 $y_v = 0.00140044$   
 $sh_v = 0.0044814$   
 $ft_v = 466.8167$   
 $fy_v = 389.0139$   
 $suv = 0.00512$   
 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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 389.0139$   
 with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.044446081$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.077488884$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07131877$

and confined core properties:

$b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.80412$   
 $cc (5A.5, TBDY) = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.05305581$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0924687$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08510586$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16131742$   
 $Mu = MRc (4.14) = 8.6158E+008$   
 $u = su (4.1) = 6.7307746E-006$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.5528E+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.5528E+006$   
 $V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{ColO}$   
 $V_{ColO} = 1.5528E+006$   
 $knl = 1$  (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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $Mu = 57.90343$   
 $Vu = 0.00030591$   
 $d = 0.8 \cdot h = 760.00$   
 $Nu = 20792.019$

$A_g = 427500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$   
where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 977392.20$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$s/d = 0.13157895$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$

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

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

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

$s/d = 1.25$

$V_{s,c2} = 134042.359$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

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

$s/d = 0.41666667$

$V_f$  ((11-3)-(11.4), ACI 440) = 477918.239

$f = 0.95$ , 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  $V_f(\alpha, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\alpha = 45^\circ$  and  $\alpha = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\alpha = b1 + 90^\circ = 90.00$

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

total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 907.00

$f_{fe}$  ((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:  $V_s + V_f \leq 1.3051E+006$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.5528E+006$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$

$V_{Col0} = 1.5528E+006$

$k_{nl} = 1$  (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).

$\lambda = 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 57.90455$

$\nu_u = 0.00030591$

$d = 0.8 * h = 760.00$

$Nu = 20792.019$   
 $Ag = 427500.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs_{jacket} + Vs_{core} = 1.1114E+006$   
 where:  
 $Vs_{jacket} = Vs_{j1} + Vs_{j2} = 977392.20$   
 $Vs_{j1} = 314161.779$  is calculated for section web jacket, with:  
 $d = 360.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 100.00$   
 $Vs_{j1}$  is multiplied by  $Col_{j1} = 1.00$   
 $s/d = 0.27777778$   
 $Vs_{j2} = 663230.422$  is calculated for section flange jacket, with:  
 $d = 760.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 100.00$   
 $Vs_{j2}$  is multiplied by  $Col_{j2} = 1.00$   
 $s/d = 0.13157895$   
 $Vs_{core} = Vs_{c1} + Vs_{c2} = 134042.359$   
 $Vs_{c1} = 0.00$  is calculated for section web core, with:  
 $d = 200.00$   
 $Av = 100530.965$   
 $fy = 555.56$   
 $s = 250.00$   
 $Vs_{c1}$  is multiplied by  $Col_{c1} = 0.00$   
 $s/d = 1.25$   
 $Vs_{c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $Av = 100530.965$   
 $fy = 555.56$   
 $s = 250.00$   
 $Vs_{c2}$  is multiplied by  $Col_{c2} = 1.00$   
 $s/d = 0.41666667$   
 $Vf$  ((11-3)-(11.4), ACI 440) = 477918.239  
 $f = 0.95$ , 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  $Vf(a, \dots)$ , 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:  $a_1 = b_1 + 90^\circ = 90.00$   
 $Vf = \text{Min}(|Vf(45, a_1)|, |Vf(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL * t / NoDir = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 907.00  
 $ffe$  ((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:  $Vs + Vf \leq 1.3051E+006$   
 $bw = 450.00$

-----  
 -----  
 End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At local axis: 2  
 -----  
 -----

Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjtcs

Constant Properties

-----  
 Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $E_{cc} = 200.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Secondary 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  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
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

Bending Moment,  $M = -164532.52$   
Shear Force,  $V_2 = 8039.906$   
Shear Force,  $V_3 = -166.1154$   
Axial Force,  $F = -22426.397$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 2475.575$   
-Compression:  $As_{l,com} = 1539.38$   
-Middle:  $As_{l,mid} = 2676.637$   
Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten,jacket} = 1859.823$   
-Compression:  $As_{l,com,jacket} = 1231.504$   
-Middle:  $As_{l,mid,jacket} = 2060.885$   
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten,core} = 615.7522$   
-Compression:  $As_{l,com,core} = 307.8761$   
-Middle:  $As_{l,mid,core} = 615.7522$   
Mean Diameter of Tension Reinforcement,  $Db_L = 16.72727$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.00120614$

$$u = y + p = 0.00120614$$

- Calculation of  $y$  -

$$y = (M_y * L_s / 3) / E_{eff} = 0.00120614 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 6.7036E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 990.4713$$

$$\text{From table 10.5, ASCE 41-17: } E_{eff} = \text{factor} * E_c * I_g = 1.8350E+014$$

$$\text{factor} = 0.30$$

$$A_g = 562500.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * A_{\text{jacket}} + f_c'_{\text{core}} * A_{\text{core}}) / A_{\text{section}} = 33.00$$

$$N = 22426.397$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 6.1166E+014$$

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:

$$\text{flange width, } b = 950.00$$

$$\text{web width, } b_w = 450.00$$

$$\text{flange thickness, } t = 450.00$$

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

$$y_{\text{ten}} = 2.8727233E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$$

$$d = 707.00$$

$$y = 0.23385327$$

$$A = 0.01007021$$

$$B = 0.00604627$$

$$\text{with } p_t = 0.00368581$$

$$p_c = 0.00229194$$

$$p_v = 0.00398517$$

$$N = 22426.397$$

$$b = 950.00$$

$$" = 0.06082037$$

$$y_{\text{comp}} = 1.3500408E-005$$

$$\text{with } f_c' \text{ (12.3, (ACI 440))} = 33.25688$$

$$f_c = 33.00$$

$$f_l = 0.43533893$$

$$b = b_{\text{max}} = 950.00$$

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

$$A_g = 0.5625$$

$$g = p_t + p_c + p_v = 0.00996292$$

$$r_c = 40.00$$

$$A_e / A_c = 0.30198841$$

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

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 26999.444$$

$$y = 0.23229127$$

$$A = 0.00988762$$

$$B = 0.00593898$$

$$\text{with } E_s = 200000.00$$

$$\text{CONFIRMATION: } y = 0.2329828 < t/d$$

Calculation of ratio  $I_b / I_d$

Inadequate Lap Length with  $I_b / I_d = 0.30$

- Calculation of  $\rho$  -

From table 10-8:  $\rho = 0.00$

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.51791795$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00568407$

jacket:  $s_1 = A_{v1} * L_{stir1} / (s_1 * A_g) = 0.00301593$

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

$L_{stir1} = 2160.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} * L_{stir2} / (s_2 * A_g) = 0.00056047$

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

$L_{stir2} = 1568.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

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

where  $f = 2 * t_f / b_w$  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.

$N_{UD} = 22426.397$

$A_g = 562500.00$

$f_{cE} = (f_{c,jacket} * Area_{jacket} + f_{c,core} * Area_{core}) / section\_area = 33.00$

$f_{yIE} = (f_{y,ext\_Long\_Reinf} * Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} * Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 555.56$

$f_{yIE} = (f_{y,ext\_Trans\_Reinf} * s_1 + f_{y,int\_Trans\_Reinf} * s_2) / (s_1 + s_2) = 555.56$

$\rho_l = Area_{Tot\_Long\_Rein} / (b * d) = 0.00996292$

$b = 950.00$

$d = 707.00$

$f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 7

column C1, Floor 1

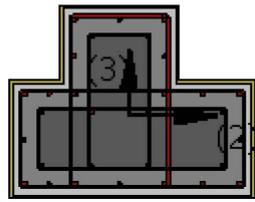
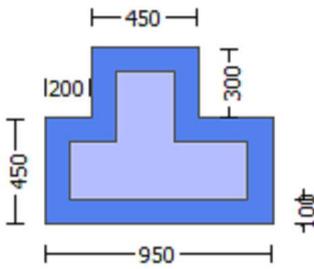
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjctcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Secondary 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

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $Ecc = 200.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary 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

Inadequate Lap Length with  $l_o/l_{o,min} = l_b/l_d = 0.30$

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,  $NoDir = 1$   
Fiber orientations,  $bi = 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties  
-----

EDGE -A-  
Bending Moment,  $M_a = -332414.048$   
Shear Force,  $V_a = 166.1154$   
EDGE -B-  
Bending Moment,  $M_b = -164532.52$   
Shear Force,  $V_b = -166.1154$   
BOTH EDGES  
Axial Force,  $F = -22426.397$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_{lt} = 0.00$   
-Compression:  $As_{lc} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{l,ten} = 2475.575$   
-Compression:  $As_{l,com} = 1539.38$   
-Middle:  $As_{l,mid} = 2676.637$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.72727$

-----  
New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 1.2388E+006$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{CoI} = 1.2388E+006$   
 $V_{CoI} = 1.2388E+006$   
 $k_{nl} = 1.00$   
 $displacement\_ductility\_demand = 1.2192476E-006$

-----  
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:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 25.00$ , but  $f_c^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 164532.52$   
 $V_u = 166.1154$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 22426.397$   
 $A_g = 337500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 842449.486$   
where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 753982.237$   
 $V_{s,j1} = 471238.898$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col_{j1} = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 282743.339$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col_{j2} = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 88467.249$   
 $V_{s,c1} = 88467.249$  is calculated for section web core, with:  
 $d = 440.00$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

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

$$s/d = 1.25$$

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

$f = 0.95$ , 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,  $tf1 = NL * t / \text{NoDir} = 1.016$

$$dfv = d \text{ (figure 11.2, ACI 440)} = 707.00$$

$$ffe((11-5), ACI 440) = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 896810.169$$

$$bw = 450.00$$

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  $\theta = 1.4705773E-009$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00120614 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 6.7036E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 990.4713$$

$$\text{From table 10.5, ASCE 41-17: } E_{eff} = \text{factor} * E_c * I_g = 1.8350E+014$$

$$\text{factor} = 0.30$$

$$A_g = 562500.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$$

$$N = 22426.397$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 6.1166E+014$$

Calculation of Yielding Moment  $M_y$

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

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

$$\text{flange width, } b = 950.00$$

$$\text{web width, } bw = 450.00$$

$$\text{flange thickness, } t = 450.00$$

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

$$y_{\text{ten}} = 2.8727233E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$$

$$d = 707.00$$

$$y = 0.23385327$$

$$A = 0.01007021$$

$$B = 0.00604627$$

$$\text{with } pt = 0.00368581$$

pc = 0.00229194  
pv = 0.00398517  
N = 22426.397  
b = 950.00  
" = 0.06082037  
y\_comp = 1.3500408E-005  
with fc\* (12.3, (ACI 440)) = 33.25688  
fc = 33.00  
fl = 0.43533893  
b = bmax = 950.00  
h = hmax = 750.00  
Ag = 0.5625  
g = pt + pc + pv = 0.00996292  
rc = 40.00  
Ae/Ac = 0.30198841  
Effective FRP thickness, tf = NL\*t\*Cos(b1) = 1.016  
effective strain from (12.5) and (12.12), efe = 0.004  
fu = 0.01  
Ef = 64828.00  
Ec = 26999.444  
y = 0.23229127  
A = 0.00988762  
B = 0.00593898  
with Es = 200000.00  
CONFIRMATION: y = 0.2329828 < t/d

-----  
-----  
Calculation of ratio lb/d

-----  
Inadequate Lap Length with lb/d = 0.30

-----  
End Of Calculation of Shear Capacity for element: column JTC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
-----

## Calculation No. 8

column C1, Floor 1

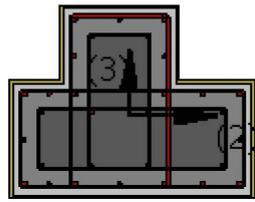
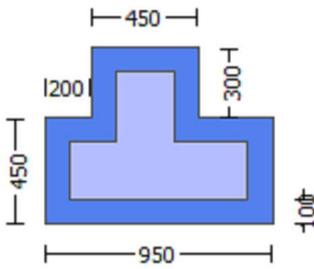
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( u)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3  
 (Bending local axis: 2)  
 Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:

Jacket

New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 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,  $f_s = 1.25 * f_{sm} = 694.45$

Existing Column

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $E_{cc} = 200.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.02437

Element Length,  $L = 3000.00$

Secondary 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

Inadequate Lap Length with  $l_o/l_{o,min} = 0.30$

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

At local axis: 3  
EDGE -A-  
Shear Force, Va = -4.9265533E-005  
EDGE -B-  
Shear Force, Vb = 4.9265533E-005  
BOTH EDGES  
Axial Force, F = -20792.019  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 6691.592  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 2475.575  
-Compression: Asl,com = 1539.38  
-Middle: Asl,mid = 2676.637

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.51791795$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 635124.647$   
with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 9.5269E+008$   
 $M_{u1+} = 9.5269E+008$ , 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  
 $M_{u1-} = 6.8428E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 9.5269E+008$   
 $M_{u2+} = 9.5269E+008$ , 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  
 $M_{u2-} = 6.8428E+008$ , 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:  
 $\phi_u = 8.7398457E-006$   
 $M_u = 9.5269E+008$

with full section properties:

$$b = 950.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093808$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01211878$$

$$\phi_u \text{ ((5.4c), TBDY)} = a_s e^* \phi_{s,\min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.04642716$$

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

$$\phi_x = 0.03444474$$

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

$$a_f = 0.28545185$$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 160566.667$

$$b_{\max} = 950.00$$

hmax = 750.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

fy = 0.03444474  
Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
af = 0.28545185  
with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$   
bmax = 950.00  
hmax = 750.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

R = 40.00  
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015

ase ((5.4d), TBDY) =  $(ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.53070105$

ase1 =  $Max(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

ase2 ( $\geq ase1$ ) =  $Max(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min}*F_{ywe} = Min(psh_x*F_{ywe}, psh_y*F_{ywe}) = 2.48363$

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)

$psh_x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.48363$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00301593$   
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00056047$   
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

$psh_y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.97078$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00  
s1 = 100.00

$s_2 = 250.00$   
 $fy_{we1} = 694.45$   
 $fy_{we2} = 694.45$   
 $f_{ce} = 33.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $y_1 = 0.00140044$   
 $sh_1 = 0.0044814$   
 $ft_1 = 466.8167$   
 $fy_1 = 389.0139$   
 $su_1 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \text{min} = lb/d = 0.30$   
 $su_1 = 0.4 * esu_1 \text{nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu_1 \text{nominal} = 0.08$ ,  
 For calculation of  $esu_1 \text{nominal}$  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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = (fs_{\text{jacket}} * A_{sl, \text{ten, jacket}} + fs_{\text{core}} * A_{sl, \text{ten, core}}) / A_{sl, \text{ten}} = 389.0139$   
 with  $Es_1 = (Es_{\text{jacket}} * A_{sl, \text{ten, jacket}} + Es_{\text{core}} * A_{sl, \text{ten, core}}) / A_{sl, \text{ten}} = 200000.00$   
 $y_2 = 0.00140044$   
 $sh_2 = 0.0044814$   
 $ft_2 = 466.8167$   
 $fy_2 = 389.0139$   
 $su_2 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \text{min} = lb/lb, \text{min} = 0.30$   
 $su_2 = 0.4 * esu_2 \text{nominal} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu_2 \text{nominal} = 0.08$ ,  
 For calculation of  $esu_2 \text{nominal}$  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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{\text{jacket}} * A_{sl, \text{com, jacket}} + fs_{\text{core}} * A_{sl, \text{com, core}}) / A_{sl, \text{com}} = 389.0139$   
 with  $Es_2 = (Es_{\text{jacket}} * A_{sl, \text{com, jacket}} + Es_{\text{core}} * A_{sl, \text{com, core}}) / A_{sl, \text{com}} = 200000.00$   
 $y_v = 0.00140044$   
 $sh_v = 0.0044814$   
 $ft_v = 466.8167$   
 $fy_v = 389.0139$   
 $suv = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \text{min} = lb/d = 0.30$   
 $suv = 0.4 * esuv \text{nominal} ((5.5), \text{TBDY}) = 0.032$   
 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  $y_v, sh_v, ft_v, fy_v$ , 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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{\text{jacket}} * A_{sl, \text{mid, jacket}} + fs_{\text{mid}} * A_{sl, \text{mid, core}}) / A_{sl, \text{mid}} = 389.0139$   
 with  $Es_v = (Es_{\text{jacket}} * A_{sl, \text{mid, jacket}} + Es_{\text{mid}} * A_{sl, \text{mid, core}}) / A_{sl, \text{mid}} = 200000.00$   
 $1 = A_{sl, \text{ten}} / (b * d) * (fs_1 / f_c) = 0.04344945$   
 $2 = A_{sl, \text{com}} / (b * d) * (fs_2 / f_c) = 0.02701806$   
 $v = A_{sl, \text{mid}} / (b * d) * (fsv / f_c) = 0.04697834$   
 and confined core properties:  
 $b = 890.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, \text{TBDY}) = 33.80412$   
 $cc (5A.5, \text{TBDY}) = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $1 = A_{sl, \text{ten}} / (b * d) * (fs_1 / f_c) = 0.04843381$   
 $2 = A_{sl, \text{com}} / (b * d) * (fs_2 / f_c) = 0.03011747$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05236752$$

Case/Assumption: Unconfined full section - Steel rupture  
satisfies Eq. (4.3)

--->

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

--->

$$s_u(4.9) = 0.17139647$$

$$M_u = M_{Rc}(4.14) = 9.5269E+008$$

$$u = s_u(4.1) = 8.7398457E-006$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $M_{u1}$ -

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

$$u = 8.8144127E-006$$

$$M_u = 6.8428E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear\_factor} \cdot \text{Max}(\alpha, \alpha_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \alpha_c = 0.01211878$$

$$\alpha_{we}((5.4c), TBDY) = \alpha_{se} \cdot \text{sh}_{, \min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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)

$$f_x = 0.03444474$$

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

$$\alpha_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$\alpha_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se}((5.4d), TBDY) = (\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.53070105$$

$$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) \cdot (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$$

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.

$A_{conf,max1} = 464100.00$  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.  
 $A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.  
 $A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

-----  
 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c$  = confinement factor = 1.02437

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1_{nominal}$  ((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  $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

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

$y2 = 0.00140044$

$sh_2 = 0.0044814$   
 $ft_2 = 466.8167$   
 $fy_2 = 389.0139$   
 $su_2 = 0.00512$   
 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  
 $lo/lo_{min} = lb/lb_{min} = 0.30$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_2 = fs_2/1.2$ , 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  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 389.0139$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.00140044$   
 $shv = 0.0044814$   
 $ftv = 466.8167$   
 $fyv = 389.0139$   
 $suv = 0.00512$   
 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  
 $lo/lo_{min} = lb/ld = 0.30$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 389.0139$   
 with  $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.05703813$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.09172662$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.0991765$   
 and confined core properties:  
 $b = 390.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 33.80412$   
 $cc (5A.5, TBDY) = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.06872961$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.11052844$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.11950537$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.17840617$   
 $Mu = MRc (4.14) = 6.8428E+008$   
 $u = su (4.1) = 8.8144127E-006$

-----  
 Calculation of ratio  $lb/ld$   
 -----

Inadequate Lap Length with  $lb/ld = 0.30$   
 -----  
 -----

-----  
 Calculation of  $Mu_{2+}$   
 -----

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 8.7398457E-006$

Mu = 9.5269E+008

with full section properties:

b = 950.00

d = 707.00

d' = 43.00

v = 0.00093808

N = 20792.019

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01211878

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

From (5.4b), TBDY: cu = 0.01211878

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+ Min( fx, fy) = 0.04642716

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.03444474

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.28545185

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 160566.667

bmax = 950.00

hmax = 750.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

fy = 0.03444474

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.28545185

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 160566.667

bmax = 950.00

hmax = 750.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

R = 40.00

Effective FRP thickness, tf = NL\*t\*Cos(b1) = 1.016

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.53070105

ase1 = Max(((Aconf,max1-AnoConf1)/Aconf,max1)\*(Aconf,min1/Aconf,max1),0) = 0.53070105

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 = 464100.00 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 = 395025.00 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 = 174733.333 is the unconfined external core area which is equal to bi2/6 as defined at (A.2).

ase2 (>=ase1) = Max(((Aconf,max2-AnoConf2)/Aconf,max2)\*(Aconf,min2/Aconf,max2),0) = 0.53070105

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 = 252164.00 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 = 111441.00 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 = 112376.00 is the unconfined internal core area which is equal to bi2/6 as defined at (A.2).

psh,min\*Fywe = Min(psh,x\*Fywe, psh,y\*Fywe) = 2.48363

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

---

$$psh_x \cdot Fy_{we} = psh1 \cdot Fy_{we1} + ps2 \cdot Fy_{we2} = 2.48363$$
$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.00301593$$

Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982

$$psh2 \text{ (5.4d)} = Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00056047$$

Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

---

$$psh_y \cdot Fy_{we} = psh1 \cdot Fy_{we1} + ps2 \cdot Fy_{we2} = 2.97078$$
$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.00357443$$

Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00070345$$

Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

---

$$Asec = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 694.45$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

$$lo/lou_{min} = lb/ld = 0.30$$

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

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

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

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

$$\text{with } fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

$$lo/lou_{min} = lb/lb_{min} = 0.30$$

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

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

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

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

$$\text{with } fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 389.0139$$

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

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

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

$$l_0/l_{ou,min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$$

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

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv\_nominal}$  and  $\gamma_v$ ,  $sh_v, ft_v, fy_v$ , it is considered

characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$$\gamma_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from } 10.3.5, \text{ ASCE } 41-17.$$

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 389.0139$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.04344945$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.02701806$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.04697834$$

and confined core properties:

$$b = 890.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.80412$$

$$c_c (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.04843381$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.03011747$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.05236752$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.17139647$$

$$M_u = M_{Rc} (4.14) = 9.5269E+008$$

$$u = s_u (4.1) = 8.7398457E-006$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_2$ -

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

$$u = 8.8144127E-006$$

$$M_u = 6.8428E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, c_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.01211878$$

$$\text{we ((5.4c), TBDY) } = a_{se} * sh_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

fy = 0.03444474  
Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$   
af = 0.28545185  
with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 160566.667$   
bmax = 950.00  
hmax = 750.00  
From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00  
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015

ase ((5.4d), TBDY) =  $(ase_1 * A_{ext} + ase_2 * A_{int})/A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

$A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$$fy_{we2} = 694.45$$

$$f_{ce} = 33.00$$

From ((5.A.5), TBDY), TBDY:  $cc = 0.00224367$

$$c = \text{confinement factor} = 1.02437$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

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

$$lo/lou, \min = lb/ld = 0.30$$

$$su_1 = 0.4 * esu_{1, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

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

For calculation of  $esu_{1, \text{nominal}}$  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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = (fs_{\text{jacket}} * Asl, \text{ten, jacket} + fs_{\text{core}} * Asl, \text{ten, core}) / Asl, \text{ten} = 389.0139$$

$$\text{with } Es_1 = (Es_{\text{jacket}} * Asl, \text{ten, jacket} + Es_{\text{core}} * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

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

$$lo/lou, \min = lb/lb, \min = 0.30$$

$$su_2 = 0.4 * esu_{2, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY:  $esu_{2, \text{nominal}} = 0.08$ ,

For calculation of  $esu_{2, \text{nominal}}$  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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_{\text{jacket}} * Asl, \text{com, jacket} + fs_{\text{core}} * Asl, \text{com, core}) / Asl, \text{com} = 389.0139$$

$$\text{with } Es_2 = (Es_{\text{jacket}} * Asl, \text{com, jacket} + Es_{\text{core}} * Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$suv = 0.00512$$

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

$$lo/lou, \min = lb/ld = 0.30$$

$$suv = 0.4 * esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

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  $y_v, sh_v, ft_v, fy_v$ , 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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs_{\text{jacket}} * Asl, \text{mid, jacket} + fs_{\text{mid}} * Asl, \text{mid, core}) / Asl, \text{mid} = 389.0139$$

$$\text{with } Es_v = (Es_{\text{jacket}} * Asl, \text{mid, jacket} + Es_{\text{mid}} * Asl, \text{mid, core}) / Asl, \text{mid} = 200000.00$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / f_c) = 0.05703813$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / f_c) = 0.09172662$$

$$v = Asl, \text{mid} / (b * d) * (fsv / f_c) = 0.0991765$$

and confined core properties:

$$b = 390.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, \text{TBDY}) = 33.80412$$

$$cc (5A.5, \text{TBDY}) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / f_c) = 0.06872961$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / f_c) = 0.11052844$$

$$v = Asl, \text{mid} / (b * d) * (fsv / f_c) = 0.11950537$$

Case/Assumption: Unconfinedsd full section - Steel rupture

satisfies Eq. (4.3)

--->

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

--->

$$\mu (4.9) = 0.17840617$$

$$\mu = M/R_c (4.14) = 6.8428E+008$$

$$u = \mu (4.1) = 8.8144127E-006$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.2263E+006$   
-----

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 1.2263E+006$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{ColO}$$

$$V_{ColO} = 1.2263E+006$$

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

-----  
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 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_c \text{ jacket} * \text{Area jacket} + f'_c \text{ core} * \text{Area core}) / \text{Area section} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)

$$M/d = 4.00$$

$$\mu = 7.32046$$

$$V_u = 4.9265533E-005$$

$$d = 0.8 * h = 600.00$$

$$N_u = 20792.019$$

$$A_g = 337500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 936062.473$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$$

$V_{s,j1} = 523602.964$  is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$$s/d = 0.16666667$$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.27777778$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.25$$

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

$f = 0.95$ , 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  $V_f(\theta, a_i)$ , 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:  $\theta = b_1 + 90^\circ = 90.00$

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

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

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.2263E+006$

$V_{r2} = V_{Col}((10.3), \text{ASCE 41-17}) = k_{nl} * V_{Col0}$

$V_{Col0} = 1.2263E+006$

$k_{nl} = 1$  (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).

$\lambda = 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/d = 4.00$

$\mu_u = 7.3142$

$V_u = 4.9265533E-005$

$d = 0.8 * h = 600.00$

$N_u = 20792.019$

$A_g = 337500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 936062.473$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$

$V_{s,j1} = 523602.964$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $Col_{j1} = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $Col_{j2} = 1.00$

$s/d = 0.27777778$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col_{c1} = 1.00$

$s/d = 0.56818182$

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

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col_{c2} = 0.00$

s/d = 1.25

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 + cota)sinα which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(α), is implemented for every different fiber orientation ai, as well as for 2 crack directions, α = 45° and α = -45° to take into consideration the cyclic seismic loading.

orientation 1: α1 = b1 + 90° = 90.00

Vf = Min(|Vf(45, α1)|, |Vf(-45, α1)|), with:

total thickness per orientation, tf1 = NL\*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 <= 1.0304E+006

bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjtcs

Constant Properties

Knowledge Factor, K = 1.00

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

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, fc = fcm = 33.00

New material of Secondary Member: Steel Strength, fs = fsm = 555.56

Concrete Elasticity, Ec = 26999.444

Steel Elasticity, Es = 200000.00

Existing Column

New material of Secondary Member: Concrete Strength, fc = fcm = 33.00

New material of Secondary Member: Steel Strength, fs = fsm = 555.56

Concrete Elasticity, Ec = 26999.444

Steel Elasticity, Es = 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, fs = 1.25\*fsm = 694.45

Existing Column

New material: Steel Strength, fs = 1.25\*fsm = 694.45

#####

Max Height, Hmax = 750.00

Min Height, Hmin = 450.00

Max Width, Wmax = 950.00

Min Width, Wmin = 450.00

Eccentricity, Ecc = 200.00

Jacket Thickness, tj = 100.00

Cover Thickness, c = 25.00

Mean Confinement Factor overall section = 1.02437

Element Length, L = 3000.00

Secondary 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

Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$

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,  $ε_{fu} = 0.01$

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,  $V_a = 0.00030591$

EDGE -B-

Shear Force,  $V_b = -0.00030591$

BOTH EDGES

Axial Force,  $F = -20792.019$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 0.00$

-Compression:  $A_{sl,c} = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 2682.92$

-Compression:  $A_{sl,com} = 1539.38$

-Middle:  $A_{sl,mid} = 2469.292$

-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.55437584$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 860817.439$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.2912E+009$

$M_{u1+} = 1.2912E+009$ , 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

$M_{u1-} = 8.6158E+008$ , 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.2912E+009$

$M_{u2+} = 1.2912E+009$ , 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

$M_{u2-} = 8.6158E+008$ , 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:

$\phi_u = 7.0548964E-006$

$M_u = 1.2912E+009$

-----  
with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.019$

$f_c = 33.00$

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

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$

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

From (5.4b), TBDY:  $c_u = 0.01211878$

$w_e$  ((5.4c), TBDY) =  $a_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

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

-----  
 $f_x = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $f_y = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $R = 40.00$

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), TBDY) =  $(a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$

$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53070105$

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.

$A_{\text{conf,max2}} = 252164.00$  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.

$A_{\text{conf,min2}} = 111441.00$  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.

$A_{\text{noConf2}} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  ((5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

psh<sub>y</sub>\*Fywe = psh<sub>1</sub>\*Fywe<sub>1</sub>+ps<sub>2</sub>\*Fywe<sub>2</sub> = 2.97078  
psh<sub>1</sub> ((5.4d), TBDY) = Lstir<sub>1</sub>\*Astir<sub>1</sub>/(Asec\*s<sub>1</sub>) = 0.00357443  
Lstir<sub>1</sub> (Length of stirrups along X) = 2560.00  
Astir<sub>1</sub> (stirrups area) = 78.53982  
psh<sub>2</sub> ((5.4d), TBDY) = Lstir<sub>2</sub>\*Astir<sub>2</sub>/(Asec\*s<sub>2</sub>) = 0.00070345  
Lstir<sub>2</sub> (Length of stirrups along X) = 1968.00  
Astir<sub>2</sub> (stirrups area) = 50.26548

Asec = 562500.00

s<sub>1</sub> = 100.00

s<sub>2</sub> = 250.00

fywe<sub>1</sub> = 694.45

fywe<sub>2</sub> = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367

c = confinement factor = 1.02437

y<sub>1</sub> = 0.00140044

sh<sub>1</sub> = 0.0044814

ft<sub>1</sub> = 466.8167

fy<sub>1</sub> = 389.0139

su<sub>1</sub> = 0.00512

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 = 0.30

su<sub>1</sub> = 0.4\*esu<sub>1\_nominal</sub> ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu<sub>1\_nominal</sub> = 0.08,

For calculation of esu<sub>1\_nominal</sub> and y<sub>1</sub>, sh<sub>1</sub>,ft<sub>1</sub>,fy<sub>1</sub>, it is considered  
characteristic value fsy<sub>1</sub> = fs<sub>1</sub>/1.2, from table 5.1, TBDY.

y<sub>1</sub>, sh<sub>1</sub>,ft<sub>1</sub>,fy<sub>1</sub>, are also multiplied by Min(1,1.25\*(lb/ld)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

with fs<sub>1</sub> = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es<sub>1</sub> = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y<sub>2</sub> = 0.00140044

sh<sub>2</sub> = 0.0044814

ft<sub>2</sub> = 466.8167

fy<sub>2</sub> = 389.0139

su<sub>2</sub> = 0.00512

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 = 0.30

su<sub>2</sub> = 0.4\*esu<sub>2\_nominal</sub> ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu<sub>2\_nominal</sub> = 0.08,

For calculation of esu<sub>2\_nominal</sub> and y<sub>2</sub>, sh<sub>2</sub>,ft<sub>2</sub>,fy<sub>2</sub>, it is considered  
characteristic value fsy<sub>2</sub> = fs<sub>2</sub>/1.2, from table 5.1, TBDY.

y<sub>2</sub>, sh<sub>2</sub>,ft<sub>2</sub>,fy<sub>2</sub>, are also multiplied by Min(1,1.25\*(lb/ld)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

with fs<sub>2</sub> = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es<sub>2</sub> = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

y<sub>v</sub> = 0.00140044

sh<sub>v</sub> = 0.0044814

ft<sub>v</sub> = 466.8167

fy<sub>v</sub> = 389.0139

suv = 0.00512

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 = 0.30

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<sub>v</sub>, sh<sub>v</sub>,ft<sub>v</sub>,fy<sub>v</sub>, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y<sub>1</sub>, sh<sub>1</sub>,ft<sub>1</sub>,fy<sub>1</sub>, are also multiplied by Min(1,1.25\*(lb/ld)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs<sub>1</sub>/fc) = 0.07748884

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.04446081$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07131877$$

and confined core properties:

$$b = 390.00$$

$$d = 877.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.80412$$

$$c_c (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0924687$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.05305581$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08510586$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.19984886$$

$$\mu_u = M_{Rc} (4.14) = 1.2912E+009$$

$$u = s_u (4.1) = 7.0548964E-006$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u1}$ -

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

$$u = 6.7307746E-006$$

$$\mu_u = 8.6158E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01211878$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00  
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

$A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c =$  confinement factor = 1.02437

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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 = 0.30

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 = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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 = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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 = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04446081

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07748884

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.07131877

and confined core properties:

b = 390.00

d = 877.00

d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.05305581

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0924687

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.08510586

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16131742

Mu = MRc (4.14) = 8.6158E+008

u = su (4.1) = 6.7307746E-006

-----  
Calculation of ratio lb/ld

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{2+}$

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

$$\mu = 7.0548964E-006$$

$$\mu_u = 1.2912E+009$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.01211878$$

$$\mu_{ve} \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{,\min} * f_{yve}/f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.53070105$$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (> a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.53070105$$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

-----  
 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

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

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

$Shear\_factor = 1.00$

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1\_nominal$  ((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  $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

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

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

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

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

$Shear\_factor = 1.00$

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$

$su2 = 0.4 * esu2\_nominal$  ((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.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = (fs_{jacket} \cdot A_{s1,com,jacket} + fs_{core} \cdot A_{s1,com,core}) / A_{s1,com} = 389.0139$

with  $Es_2 = (Es_{jacket} \cdot A_{s1,com,jacket} + Es_{core} \cdot A_{s1,com,core}) / A_{s1,com} = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$suv = 0.00512$

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

$l_o/l_{o,min} = l_b/l_d = 0.30$

$suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

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  $fsv = (fs_{jacket} \cdot A_{s,mid,jacket} + fs_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 389.0139$

with  $Esv = (Es_{jacket} \cdot A_{s,mid,jacket} + Es_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.07748884$

$2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04446081$

$v = A_{s,mid} / (b \cdot d) \cdot (fsv / fc) = 0.07131877$

and confined core properties:

$b = 390.00$

$d = 877.00$

$d' = 13.00$

$fcc$  (5A.2, TBDY) = 33.80412

$cc$  (5A.5, TBDY) = 0.00224367

$c$  = confinement factor = 1.02437

$1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0924687$

$2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05305581$

$v = A_{s,mid} / (b \cdot d) \cdot (fsv / fc) = 0.08510586$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su$  (4.9) = 0.19984886

$Mu = MRc$  (4.14) = 1.2912E+009

$u = su$  (4.1) = 7.0548964E-006

-----  
Calculation of ratio  $l_b/l_d$

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Inadequate Lap Length with  $l_b/l_d = 0.30$   
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Calculation of  $Mu_2$ -  
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-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 6.7307746E-006$

$Mu = 8.6158E+008$   
-----

with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.019$

$fc = 33.00$

$co$  (5A.5, TBDY) = 0.002

Final value of  $cu$ :  $cu^* = \text{shear\_factor} \cdot \text{Max}(cu, cc) = 0.01211878$

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

From (5.4b), TBDY:  $c_u = 0.01211878$

$w_e$  ((5.4c), TBDY) =  $ase * sh_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

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

$f_x = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,e} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (\geq ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

psh1 ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367

c = confinement factor = 1.02437

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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 = 0.30

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 =  $(fs\_jacket * A_{sl,ten,jacket} + fs\_core * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

with Es1 =  $(Es\_jacket * A_{sl,ten,jacket} + Es\_core * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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 =  $(fs\_jacket * A_{sl,com,jacket} + fs\_core * A_{sl,com,core}) / A_{sl,com} = 389.0139$

with Es2 =  $(Es\_jacket * A_{sl,com,jacket} + Es\_core * A_{sl,com,core}) / A_{sl,com} = 200000.00$

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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 =  $(fs\_jacket * A_{sl,mid,jacket} + fs\_mid * A_{sl,mid,core}) / A_{sl,mid} = 389.0139$

with Esv =  $(Es\_jacket * A_{sl,mid,jacket} + Es\_mid * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$

1 =  $A_{sl,ten} / (b * d) * (fs1 / fc) = 0.04446081$

2 =  $A_{sl,com} / (b * d) * (fs2 / fc) = 0.07748884$

v =  $A_{sl,mid} / (b * d) * (fsv / fc) = 0.07131877$

and confined core properties:

$$b = 390.00$$

$$d = 877.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.80412$$

$$cc (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05305581$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.0924687$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08510586$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16131742$$

$$\mu = MR_c (4.14) = 8.6158E+008$$

$$u = s_u (4.1) = 6.7307746E-006$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.5528E+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.5528E+006$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 1.5528E+006$$

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

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 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 57.90343$$

$$V_u = 0.00030591$$

$$d = 0.8 * h = 760.00$$

$$N_u = 20792.019$$

$$A_g = 427500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$$

where:

$$V_{s,jacket} = V_{sj1} + V_{sj2} = 977392.20$$

$V_{sj1} = 314161.779$  is calculated for section web jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{sj1}$  is multiplied by  $Col_{j1} = 1.00$

$$s/d = 0.27777778$$

$V_{sj2} = 663230.422$  is calculated for section flange jacket, with:

$$d = 760.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{sj2}$  is multiplied by  $Col_{j2} = 1.00$

$$s/d = 0.13157895$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 477918.239

$f = 0.95$ , 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  $\theta$  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:  $\theta = b_1 + 90^\circ = 90.00$

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

total thickness per orientation,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 907.00

$f_{fe}$  ((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:  $V_s + V_f \leq 1.3051E+006$

$b_w = 450.00$

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 1.5528E+006$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Col0}$

$V_{Col0} = 1.5528E+006$

$k_{nl} = 1$  (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).

-----  
 $\rho = 1$  (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/d = 4.00$

$\mu_u = 57.90455$

$V_u = 0.00030591$

$d = 0.8 \cdot h = 760.00$

$N_u = 20792.019$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 977392.20$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$s/d = 0.13157895$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$

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

$d = 200.00$

Av = 100530.965

fy = 555.56

s = 250.00

Vs,c1 is multiplied by Col,c1 = 0.00

s/d = 1.25

Vs,c2 = 134042.359 is calculated for section flange core, with:

d = 600.00

Av = 100530.965

fy = 555.56

s = 250.00

Vs,c2 is multiplied by Col,c2 = 1.00

s/d = 0.41666667

Vf ((11-3)-(11.4), ACI 440) = 477918.239

f = 0.95, for fully-wrapped sections

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

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

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

orientation 1:  $\theta = 45^\circ$

Vf = Min(|Vf(45,  $\alpha_1$ )|, |Vf(-45,  $\alpha_1$ )|), with:

total thickness per orientation, tf1 = NL\*t/NoDir = 1.016

dfv = d (figure 11.2, ACI 440) = 907.00

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 <= 1.3051E+006

bw = 450.00

-----  
End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 2

-----  
Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
Section Type: rcjtcs

Constant Properties

-----  
Knowledge Factor,  $\phi = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $E_{cc} = 200.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary 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  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
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

Bending Moment,  $M = 366061.641$   
Shear Force,  $V_2 = 8039.906$   
Shear Force,  $V_3 = -166.1154$   
Axial Force,  $F = -22426.397$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_{lt} = 0.00$   
-Compression:  $As_{lc} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{l,ten} = 2682.92$   
-Compression:  $As_{l,com} = 1539.38$   
-Middle:  $As_{l,mid} = 2469.292$   
Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{l,ten,jacket} = 2375.044$   
-Compression:  $As_{l,com,jacket} = 1231.504$   
-Middle:  $As_{l,mid,jacket} = 1545.664$   
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{l,ten,core} = 307.8761$   
-Compression:  $As_{l,com,core} = 307.8761$   
-Middle:  $As_{l,mid,core} = 923.6282$   
Mean Diameter of Tension Reinforcement,  $DbL = 17.45455$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.00031154$   
 $u = y + p = 0.00031154$

- Calculation of  $y$  -

$y = (My * L_s / 3) / E_{eff} = 0.00031154$  ((4.29), Biskinis Phd))  
 $My = 8.7527E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $300.00$   
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.8095E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 22426.397$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.3651E+014$

Calculation of Yielding Moment  $My$

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

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

$y_{ten} = 2.3928489E-006$   
 with  $((10.1), ASCE 41-17) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/l_d)^{2/3}) = 311.2112$   
 $d = 907.00$   
 $y = 0.28302733$   
 $A = 0.01657149$   
 $B = 0.01009713$   
 with  $pt = 0.00657337$   
 $pc = 0.0037716$   
 $pv = 0.00604996$   
 $N = 22426.397$   
 $b = 450.00$   
 $" = 0.04740904$

$y_{comp} = 8.6876729E-006$   
 with  $f_c^* (12.3, (ACI 440)) = 33.253$   
 $f_c = 33.00$   
 $f_l = 0.43533893$   
 $b = b_{max} = 950.00$   
 $h = h_{max} = 750.00$   
 $Ag = 0.5625$   
 $g = pt + pc + pv = 0.01639493$   
 $rc = 40.00$   
 $A_e/A_c = 0.29742395$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.28134405$   
 $A = 0.01627101$   
 $B = 0.00992057$   
 with  $E_s = 200000.00$

-----  
 Calculation of ratio  $l_b/l_d$

-----  
 Inadequate Lap Length with  $l_b/l_d = 0.30$

-----  
 - 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  $V_y E / V_{CoI} O E = 0.55437584$

$d = d_{external} = 907.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00638555$

jacket:  $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.00357443$

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

$L_{stir1} = 2560.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00070345$

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

$L_{stir2} = 1968.00$ , 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.

$NUD = 22426.397$

$A_g = 562500.00$

$f_c E = (f_c \cdot \text{Area}_{jacket} + f_c \cdot \text{Area}_{core}) / \text{section\_area} = 33.00$

$f_y E = (f_y \cdot \text{ext\_Long\_Reinf} \cdot \text{Area\_ext\_Long\_Reinf} + f_y \cdot \text{int\_Long\_Reinf} \cdot \text{Area\_int\_Long\_Reinf}) / \text{Area\_Tot\_Long\_Rein} = 555.56$

$f_y E = (f_y \cdot \text{ext\_Trans\_Reinf} \cdot s_1 + f_y \cdot \text{int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$

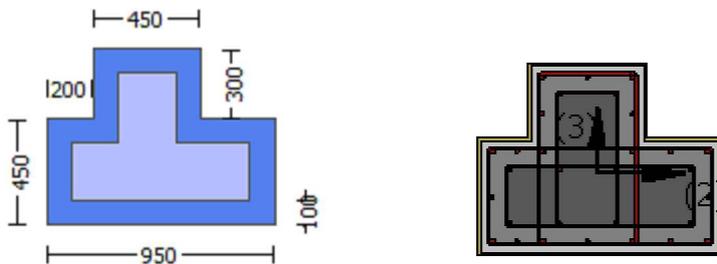
$pl = \text{Area\_Tot\_Long\_Rein} / (b \cdot d) = 0.01639493$

b = 450.00  
d = 907.00  
f<sub>cE</sub> = 33.00

End Of Calculation of Chord Rotation Capacity for element: column JTC1 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 JTC1 of floor 1  
At local axis: 2  
Integration Section: (a)  
Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
New material of Secondary 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

New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
 Concrete Elasticity,  $E_c = 26999.444$   
 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  
 New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 450.00$   
 Max Width,  $W_{max} = 950.00$   
 Min Width,  $W_{min} = 450.00$   
 Eccentricity,  $E_{cc} = 200.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary 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  
 Inadequate Lap Length with  $l_o/l_{o,min} = l_b/l_d = 0.30$   
 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,  $M_a = -2.9466E+007$   
 Shear Force,  $V_a = -9672.998$   
 EDGE -B-  
 Bending Moment,  $M_b = 440405.491$   
 Shear Force,  $V_b = 9672.998$   
 BOTH EDGES  
 Axial Force,  $F = -22758.377$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $As_t = 0.00$   
 -Compression:  $As_c = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten} = 2682.92$   
 -Compression:  $As_{l,com} = 1539.38$   
 -Middle:  $As_{l,mid} = 2469.292$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.45455$   
 -----  
 -----

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 * V_n = 1.3520E+006$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI} = 1.3520E+006$   
 $V_{CoI} = 1.3520E+006$

knl = 1.00

displacement\_ductility\_demand = 0.0192268

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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 2.9466E+007$

$V_u = 9672.998$

$d = 0.8 \cdot h = 760.00$

$N_u = 22758.377$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 1.0003E+006$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 879645.943$

$V_{s,j1} = 282743.339$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 596902.604$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 1.00$

$s/d = 0.13157895$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 120637.158$

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

$d = 200.00$

$A_v = 100530.965$

$f_y = 500.00$

$s = 250.00$

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

$s/d = 1.25$

$V_{s,c2} = 120637.158$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 500.00$

$s = 250.00$

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

$s/d = 0.41666667$

$V_f$  ((11-3)-(11.4), ACI 440) = 477918.239

$f = 0.95$ , 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) = 907.00

$f_{fe}$  ((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:  $V_s + V_f \leq 1.1360E+006$

$b_w = 450.00$

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

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

-----  
From analysis, chord rotation =  $6.0828781E-005$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00316375$  ((4.29), Biskinis Phd)  
 $M_y = 8.7538E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $3046.206$   
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.8095E+014$   
factor =  $0.30$   
 $A_g = 562500.00$   
Mean concrete strength:  $f'_c = (f'_{c\_jacket} * Area\_jacket + f'_{c\_core} * Area\_core) / Area\_section = 33.00$   
 $N = 22758.377$   
 $E_c * I_g = E_{c\_jacket} * I_{g\_jacket} + E_{c\_core} * I_{g\_core} = 9.3651E+014$   
-----  
-----

Calculation of Yielding Moment  $M_y$

Calculation of  $\phi$  and  $M_y$  according to Annex 7 -

-----  
 $y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 2.3929630E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 311.2112$   
 $d = 907.00$   
 $y = 0.28306153$   
 $A = 0.0165741$   
 $B = 0.01009974$   
with  $pt = 0.00657337$   
 $pc = 0.0037716$   
 $pv = 0.00604996$   
 $N = 22758.377$   
 $b = 450.00$   
 $" = 0.04740904$   
 $y_{comp} = 8.6873791E-006$   
with  $f'_c$  (12.3, (ACI 440)) =  $33.253$   
 $f_c = 33.00$   
 $f_l = 0.43533893$   
 $b = b_{max} = 950.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.5625$   
 $g = pt + pc + pv = 0.01639493$   
 $rc = 40.00$   
 $A_e / A_c = 0.29742395$   
Effective FRP thickness,  $t_f = N L * t * \text{Cos}(\theta_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.28135356$   
 $A = 0.01626917$   
 $B = 0.00992057$   
with  $E_s = 200000.00$   
-----  
-----

Calculation of ratio  $l_b / l_d$

Inadequate Lap Length with  $l_b / l_d = 0.30$

End Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (a)

-----  
-----

## Calculation No. 10

column C1, Floor 1

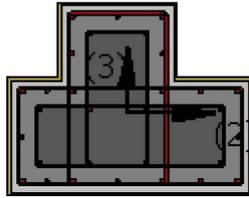
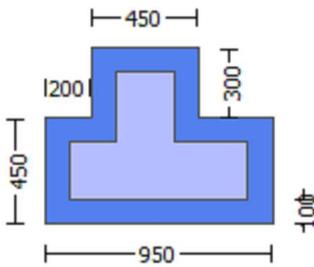
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $Ecc = 200.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.02437  
Element Length,  $L = 3000.00$   
Secondary 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  
Inadequate Lap Length with  $l_o/l_{o,min} = 0.30$   
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,  $V_a = -4.9265533E-005$   
EDGE -B-  
Shear Force,  $V_b = 4.9265533E-005$   
BOTH EDGES  
Axial Force,  $F = -20792.019$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 2475.575$   
-Compression:  $A_{sl,com} = 1539.38$   
-Middle:  $A_{sl,mid} = 2676.637$

-----  
Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.51791795$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 635124.647$   
with  
 $M_{pr1} = \text{Max}(\mu_{u1+} , \mu_{u1-}) = 9.5269E+008$   
 $\mu_{u1+} = 9.5269E+008$ , 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  
 $\mu_{u1-} = 6.8428E+008$ , 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  
 $M_{pr2} = \text{Max}(\mu_{u2+} , \mu_{u2-}) = 9.5269E+008$   
 $\mu_{u2+} = 9.5269E+008$ , 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  
 $\mu_{u2-} = 6.8428E+008$ , 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  $\mu_{u1+}$   
-----

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

u = 8.7398457E-006  
Mu = 9.5269E+008

with full section properties:

b = 950.00  
d = 707.00  
d' = 43.00  
v = 0.00093808  
N = 20792.019  
fc = 33.00  
co (5A.5, TBDY) = 0.002

Final value of cu:  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01211878$

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

From (5.4b), TBDY:  $cu = 0.01211878$

we ((5.4c), TBDY) =  $ase * sh, \min * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.04642716$

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

$fx = 0.03444474$

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

$af = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A 4.4.3(6),  $pf = 2tf / bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff,e = 881.8461$

$fy = 0.03444474$

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

$af = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A 4.4.3(6),  $pf = 2tf / bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff,e = 881.8461$

R = 40.00

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53070105$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $bi^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $bi^2/6$  as defined at (A.2).

$$psh_{min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 2.48363$$

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

$$psh_x * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 2.48363$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00301593$$

$$Lstir1 \text{ (Length of stirrups along Y)} = 2160.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00056047$$

$$Lstir2 \text{ (Length of stirrups along Y)} = 1568.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$psh_y * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 2.97078$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00357443$$

$$Lstir1 \text{ (Length of stirrups along X)} = 2560.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$$

$$Lstir2 \text{ (Length of stirrups along X)} = 1968.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$Asec = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

$$lo/lou_{min} = lb/ld = 0.30$$

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

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.

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

$$\text{with } fs1 = (fs_{jacket} * Asl_{ten,jacket} + fs_{core} * Asl_{ten,core}) / Asl_{ten} = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

$$lo/lou_{min} = lb/lb_{min} = 0.30$$

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

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.

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

$$\text{with } fs2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 389.0139$$

$$\text{with } Es2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$su_v = 0.00512$$

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fsjacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04344945

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.02701806

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.04697834

and confined core properties:

b = 890.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04843381

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.03011747

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05236752

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

v < vs,y2 - LHS eq.(4.5) is satisfied

---->

su (4.9) = 0.17139647

Mu = MRc (4.14) = 9.5269E+008

u = su (4.1) = 8.7398457E-006

-----  
Calculation of ratio lb/ld

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Inadequate Lap Length with lb/ld = 0.30  
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-----  
Calculation of Mu1-  
-----  
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Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 8.8144127E-006

Mu = 6.8428E+008  
-----

with full section properties:

b = 450.00

d = 707.00

d' = 43.00

v = 0.00198039

N = 20792.019

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01211878

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

From (5.4b), TBDY: cu = 0.01211878

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.04642716

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.03444474

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.28545185

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 160566.667

bmax = 950.00

hmax = 750.00

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $ff,e = 881.8461$

$fy = 0.03444474$

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

$af = 0.28545185$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff,e = 881.8461$

$R = 40.00$

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) =  $(ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.53070105$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2$  ( $\geq ase1$ ) =  $\text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min}*F_{ywe} = \text{Min}(psh_x*F_{ywe}, psh_y*F_{ywe}) = 2.48363$

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)

$psh_x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.48363$

$psh1$  ((5.4d), TBDY) =  $L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$psh2$  (5.4d) =  $L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$psh_y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.97078$

$psh1$  ((5.4d), TBDY) =  $L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$psh2$  ((5.4d), TBDY) =  $L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

$A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

fywe1 = 694.45  
fywe2 = 694.45  
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00224367  
c = confinement factor = 1.02437

y1 = 0.00140044  
sh1 = 0.0044814  
ft1 = 466.8167  
fy1 = 389.0139  
su1 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044  
sh2 = 0.0044814  
ft2 = 466.8167  
fy2 = 389.0139  
su2 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044  
shv = 0.0044814  
ftv = 466.8167  
fyv = 389.0139  
suv = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.05703813

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09172662

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.0991765

and confined core properties:

b = 390.00  
d = 677.00  
d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.06872961

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.11052844

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.11950537

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) = 0.17840617  
 $M_u = M_{Rc}$  (4.14) = 6.8428E+008  
 $u = s_u$  (4.1) = 8.8144127E-006

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$

-----  
Calculation of  $M_{u2+}$

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 8.7398457E-006$   
 $M_u = 9.5269E+008$

-----  
with full section properties:

$b = 950.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00093808$   
 $N = 20792.019$

$f_c = 33.00$   
 $\alpha$  (5A.5, TBDY) = 0.002

Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01211878$

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

From (5.4b), TBDY:  $\alpha = 0.01211878$

$\omega$  ((5.4c), TBDY) =  $\alpha * s_h * \text{min}(f_{ywe}/f_{ce} + \text{Min}(f_x, f_y)) = 0.04642716$

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

-----  
 $f_x = 0.03444474$

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

$\alpha_f = 0.28545185$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A 4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $f_y = 0.03444474$

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

$\alpha_f = 0.28545185$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A 4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $R = 40.00$

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) =  $(\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.53070105$

$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

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)

-----  
 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

-----  
 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

-----  
 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

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

$lo/lo_{min} = lb/ld = 0.30$

$su1 = 0.4 * esu1_{nominal}$  ((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  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

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

$y2 = 0.00140044$

$sh2 = 0.0044814$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 389.0139$$

$$\text{with } Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

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

$$lo/lou,min = lb/ld = 0.30$$

$$suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$$

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  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 389.0139$$

$$\text{with } Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.043444945$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.02701806$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.04697834$$

and confined core properties:

$$b = 890.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.80412$$

$$cc (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.04843381$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.03011747$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.05236752$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < vs,y2$  - LHS eq.(4.5) is satisfied

---->

$$su (4.9) = 0.17139647$$

$$Mu = MRc (4.14) = 9.5269E+008$$

$$u = su (4.1) = 8.7398457E-006$$

-----  
Calculation of ratio lb/ld

-----  
Inadequate Lap Length with lb/ld = 0.30  
-----  
-----

-----  
Calculation of Mu2-  
-----  
-----

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.8144127E-006$$

$$Mu = 6.8428E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \alpha = 0.01211878$$

$$\omega_e ((5.4c), \text{TBDY}) = \alpha_e^* \cdot \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$\alpha_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.03444474$$

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

$$\alpha_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

$$f_u, f = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$\alpha_e ((5.4d), \text{TBDY}) = (\alpha_e1 * A_{ext} + \alpha_e2 * A_{int}) / A_{sec} = 0.53070105$$

$$\alpha_e1 = \text{Max}(((A_{conf, \max1} - A_{noConf1}) / A_{conf, \max1}) * (A_{conf, \min1} / A_{conf, \max1}), 0) = 0.53070105$$

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.

$A_{conf, \max1} = 464100.00$  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.

$A_{conf, \min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_e2 (> \alpha_e1) = \text{Max}(((A_{conf, \max2} - A_{noConf2}) / A_{conf, \max2}) * (A_{conf, \min2} / A_{conf, \max2}), 0) = 0.53070105$$

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.

$A_{conf, \max2} = 252164.00$  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.

$A_{conf, \min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\rho_{sh, \min} * f_{ywe} = \text{Min}(\rho_{sh, x} * f_{ywe}, \rho_{sh, y} * f_{ywe}) = 2.48363$$

Expression (5.4d) for  $\rho_{sh, \min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without

earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.48363  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00301593  
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
psh2 (5.4d) = Lstir2\*Astir2/(Asec\*s2) = 0.00056047  
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00357443  
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00070345  
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367

c = confinement factor = 1.02437

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

$$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = (fs\_jacket * Asl\_mid\_jacket + fs\_mid * Asl\_mid\_core) / Asl\_mid = 389.0139$$

$$\text{with } Esv = (Es\_jacket * Asl\_mid\_jacket + Es\_mid * Asl\_mid\_core) / Asl\_mid = 200000.00$$

$$1 = Asl\_ten / (b * d) * (fs1 / fc) = 0.05703813$$

$$2 = Asl\_com / (b * d) * (fs2 / fc) = 0.09172662$$

$$v = Asl\_mid / (b * d) * (fsv / fc) = 0.0991765$$

and confined core properties:

$$b = 390.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.80412$$

$$cc (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = Asl\_ten / (b * d) * (fs1 / fc) = 0.06872961$$

$$2 = Asl\_com / (b * d) * (fs2 / fc) = 0.11052844$$

$$v = Asl\_mid / (b * d) * (fsv / fc) = 0.11950537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$  - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.17840617$$

$$Mu = MRc (4.14) = 6.8428E+008$$

$$u = su (4.1) = 8.8144127E-006$$

Calculation of ratio  $lb/ld$

Inadequate Lap Length with  $lb/ld = 0.30$

Calculation of Shear Strength  $Vr = Min(Vr1, Vr2) = 1.2263E+006$

Calculation of Shear Strength at edge 1,  $Vr1 = 1.2263E+006$

$$Vr1 = VCol ((10.3), ASCE 41-17) = knl * VCol0$$

$$VCol0 = 1.2263E+006$$

$$knl = 1 \text{ (zero step-static loading)}$$

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).

$$= 1 \text{ (normal-weight concrete)}$$

Mean concrete strength:  $fc' = (fc'_jacket * Area\_jacket + fc'_core * Area\_core) / Area\_section = 33.00$ , but  $fc'^{0.5} <= 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/d = 4.00$$

$$Mu = 7.32046$$

$$Vu = 4.9265533E-005$$

$$d = 0.8 * h = 600.00$$

$$Nu = 20792.019$$

$$Ag = 337500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } Vs = Vs\_jacket + Vs\_core = 936062.473$$

where:

$$Vs\_jacket = Vs\_j1 + Vs\_j2 = 837764.743$$

$Vs\_j1 = 523602.964$  is calculated for section web jacket, with:

$$d = 600.00$$

$$Av = 157079.633$$

$$fy = 555.56$$

$$s = 100.00$$

$Vs\_j1$  is multiplied by  $Col\_j1 = 1.00$

$$s/d = 0.16666667$$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.27777778$$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.25$$

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

$f = 0.95$ , 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  $V_f(\theta, a_i)$ , 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:  $\theta = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (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:  $V_s + V_f \leq 1.0304E+006$

$$b_w = 450.00$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.2263E+006$

$V_{r2} = V_{Col}((10.3), ASCE 41-17) = knl \cdot V_{Col0}$

$$V_{Col0} = 1.2263E+006$$

$knl = 1$  (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).

$\lambda = 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 7.3142$$

$$V_u = 4.9265533E-005$$

$$d = 0.8 \cdot h = 600.00$$

$$N_u = 20792.019$$

$$A_g = 337500.00$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 936062.473$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$$

$V_{s,j1} = 523602.964$  is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$$s/d = 0.16666667$$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.27777778$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.25$$

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

$f = 0.95$ , 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:  $\theta = b1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|), \text{ with:}$$

total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$

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

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

$$E_f = 64828.00$$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 1.0304E+006$

$$b_w = 450.00$$

-----  
End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 3

-----  
Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjtcs

Constant Properties

-----  
Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $Ecc = 200.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.02437  
Element Length,  $L = 3000.00$   
Secondary 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  
Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$   
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  
-----

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = 0.00030591$   
EDGE -B-  
Shear Force,  $V_b = -0.00030591$   
BOTH EDGES  
Axial Force,  $F = -20792.019$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 2682.92$   
-Compression:  $A_{sl,com} = 1539.38$   
-Middle:  $A_{sl,mid} = 2469.292$

-----  
-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.55437584$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 860817.439$   
with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.2912E+009$   
 $M_{u1+} = 1.2912E+009$ , 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  
 $M_{u1-} = 8.6158E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.2912E+009$

Mu2+ = 1.2912E+009, 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

Mu2- = 8.6158E+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 Mu1+  
-----

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

$$\mu = 7.0548964E-006$$

$$Mu = 1.2912E+009$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01211878$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53070105$$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 2.48363$$

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)

---

$$psh_{,x} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 2.48363$$

$$psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2160.00$$

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

$$psh_2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1568.00$$

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

---

$$psh_{,y} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 2.97078$$

$$psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$$

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

$$psh_2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$$

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

---

$$A_{sec} = 562500.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

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

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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

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.

$$y_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs_1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 389.0139$$

$$\text{with } Es_1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

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

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{2,nominal} = 0.08,$$

For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered

characteristic value  $f_{sy2} = f_{s2}/1.2$ , 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  $f_{s2} = (f_{s,jacket} \cdot A_{s1,com,jacket} + f_{s,core} \cdot A_{s1,com,core})/A_{s1,com} = 389.0139$

with  $E_{s2} = (E_{s,jacket} \cdot A_{s1,com,jacket} + E_{s,core} \cdot A_{s1,com,core})/A_{s1,com} = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$suv = 0.00512$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

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  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 389.0139$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.07748884$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.04446081$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07131877$

and confined core properties:

$b = 390.00$

$d = 877.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 33.80412$

$cc (5A.5, TBDY) = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0924687$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.05305581$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08510586$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.19984886$

$Mu = MRc (4.14) = 1.2912E+009$

$u = su (4.1) = 7.0548964E-006$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----  
-----

-----  
Calculation of  $Mu_1$ -  
-----  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 6.7307746E-006$

$Mu = 8.6158E+008$

-----  
with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.019$

$f_c = 33.00$

$co (5A.5, TBDY) = 0.002$

Final value of  $cu$ :  $cu^* = \text{shear\_factor} \cdot \text{Max}(cu, cc) = 0.01211878$

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

From (5.4b), TBDY:  $c_u = 0.01211878$

$w_e$  ((5.4c), TBDY) =  $a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

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

$f_x = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se}$  ((5.4d), TBDY) =  $(a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$

$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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)

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

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00357443  
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00070345  
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367

c = confinement factor = 1.02437

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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 = 0.30

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/d)^2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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/d)^2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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/d)^2/3), from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04446081

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07748884

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07131877$$

and confined core properties:

$$b = 390.00$$

$$d = 877.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.80412$$

$$c_c (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{sl, ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.05305581$$

$$2 = A_{sl, com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0924687$$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08510586$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16131742$$

$$M_u = M_{Rc} (4.14) = 8.6158E+008$$

$$u = s_u (4.1) = 6.7307746E-006$$

Calculation of ratio  $l_b / l_d$

Inadequate Lap Length with  $l_b / l_d = 0.30$

Calculation of  $M_{u2+}$

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

$$u = 7.0548964E-006$$

$$M_u = 1.2912E+009$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} \cdot \text{Max}(c_u, c_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01211878$$

$$w_e ((5.4c), TBDY) = a_{se} \cdot s_{h, min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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)

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

$A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c =$  confinement factor = 1.02437

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.07748884

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.04446081

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.07131877

and confined core properties:

b = 390.00

d = 877.00

d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0924687

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.05305581

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.08510586

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.19984886

Mu = MRc (4.14) = 1.2912E+009

u = su (4.1) = 7.0548964E-006

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Calculation of ratio lb/d  
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Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_2$ -

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

$$\mu = 6.7307746E-006$$

$$\mu_2 = 8.6158E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_2: \mu_2 = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \mu_c = 0.01211878$$

$$\mu_{cc} \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

-----  
 $A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

$Shear\_factor = 1.00$

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su_1 = 0.4 * esu_{1,nominal}$  ((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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 389.0139$

with  $Es_1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

$Shear\_factor = 1.00$

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$su_2 = 0.4 * esu_{2,nominal}$  ((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  $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 389.0139$   
 with  $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$   
 $y_v = 0.00140044$   
 $sh_v = 0.0044814$   
 $ft_v = 466.8167$   
 $fy_v = 389.0139$   
 $suv = 0.00512$   
 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  
 $l_o/l_{o,min} = l_b/l_d = 0.30$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 389.0139$   
 with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.044446081$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.077488884$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07131877$

and confined core properties:

$b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.80412$   
 $cc (5A.5, TBDY) = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.05305581$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0924687$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08510586$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16131742$   
 $Mu = MRc (4.14) = 8.6158E+008$   
 $u = su (4.1) = 6.7307746E-006$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.5528E+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.5528E+006$   
 $V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{ColO}$   
 $V_{ColO} = 1.5528E+006$   
 $knl = 1$  (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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $Mu = 57.90343$   
 $Vu = 0.00030591$   
 $d = 0.8 \cdot h = 760.00$   
 $Nu = 20792.019$

Ag = 427500.00  
From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$   
where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 977392.20$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

d = 360.00

Av = 157079.633

fy = 555.56

s = 100.00

$V_{s,j1}$  is multiplied by Col,j1 = 1.00

s/d = 0.27777778

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

d = 760.00

Av = 157079.633

fy = 555.56

s = 100.00

$V_{s,j2}$  is multiplied by Col,j2 = 1.00

s/d = 0.13157895

$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$

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

d = 200.00

Av = 100530.965

fy = 555.56

s = 250.00

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

s/d = 1.25

$V_{s,c2} = 134042.359$  is calculated for section flange core, with:

d = 600.00

Av = 100530.965

fy = 555.56

s = 250.00

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

s/d = 0.41666667

Vf ((11-3)-(11.4), ACI 440) = 477918.239

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  $\alpha$  is the angle of the crack direction (see KANEPE).

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

orientation 1:  $\alpha = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45,  $\alpha$ )|, |Vf(-45,  $\alpha$ )|), with:

total thickness per orientation, tf1 = NL\*t/NoDir = 1.016

dfv = d (figure 11.2, ACI 440) = 907.00

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:  $V_s + V_f \leq 1.3051E+006$

bw = 450.00

-----  
Calculation of Shear Strength at edge 2, Vr2 = 1.5528E+006

Vr2 = VCol ((10.3), ASCE 41-17) = knl\*VColO

VColO = 1.5528E+006

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 Vf is the contribution of FRPs (11.3), ACI 440).

-----  
= 1 (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 57.90455

Vu = 0.00030591

d = 0.8\*h = 760.00

$N_u = 20792.019$   
 $A_g = 427500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 977392.20$   
 $V_{s,j1} = 314161.779$  is calculated for section web jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:  
 $d = 760.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.13157895$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 477918.239  
 $f = 0.95$ , 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,  $t_{f1} = NL * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 907.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 1.3051E+006$   
 $b_w = 450.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At local axis: 2  
 -----

Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
 At local axis: 2  
 Integration Section: (a)  
 Section Type: rcjtcs

Constant Properties

-----  
 Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $E_{cc} = 200.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Secondary 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  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
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

Bending Moment,  $M = -399933.566$   
Shear Force,  $V_2 = -9672.998$   
Shear Force,  $V_3 = 199.8573$   
Axial Force,  $F = -22758.377$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 2475.575$   
-Compression:  $As_{l,com} = 1539.38$   
-Middle:  $As_{l,mid} = 2676.637$   
Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten,jacket} = 1859.823$   
-Compression:  $As_{l,com,jacket} = 1231.504$   
-Middle:  $As_{l,mid,jacket} = 2060.885$   
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten,core} = 615.7522$   
-Compression:  $As_{l,com,core} = 307.8761$   
-Middle:  $As_{l,mid,core} = 615.7522$   
Mean Diameter of Tension Reinforcement,  $Db_L = 16.72727$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.04443716$

$$u = y + p = 0.04443716$$

- Calculation of  $y$  -

$$y = (M_y * L_s / 3) / E_{eff} = 0.00243716 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 6.7046E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 2001.096$$

$$\text{From table 10.5, ASCE 41-17: } E_{eff} = \text{factor} * E_c * I_g = 1.8350E+014$$

$$\text{factor} = 0.30$$

$$A_g = 562500.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * A_{\text{jacket}} + f_c'_{\text{core}} * A_{\text{core}}) / A_{\text{section}} = 33.00$$

$$N = 22758.377$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 6.1166E+014$$

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:

$$\text{flange width, } b = 950.00$$

$$\text{web width, } b_w = 450.00$$

$$\text{flange thickness, } t = 450.00$$

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

$$y_{\text{ten}} = 2.8728328E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$$

$$d = 707.00$$

$$y = 0.23388249$$

$$A = 0.01007179$$

$$B = 0.00604786$$

$$\text{with } p_t = 0.00368581$$

$$p_c = 0.00229194$$

$$p_v = 0.00398517$$

$$N = 22758.377$$

$$b = 950.00$$

$$" = 0.06082037$$

$$y_{\text{comp}} = 1.3500043E-005$$

$$\text{with } f_c' \text{ (12.3, (ACI 440))} = 33.25688$$

$$f_c = 33.00$$

$$f_l = 0.43533893$$

$$b = b_{\text{max}} = 950.00$$

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

$$A_g = 0.5625$$

$$g = p_t + p_c + p_v = 0.00996292$$

$$r_c = 40.00$$

$$A_e / A_c = 0.30198841$$

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

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 26999.444$$

$$y = 0.23229755$$

$$A = 0.0098865$$

$$B = 0.00593898$$

$$\text{with } E_s = 200000.00$$

CONFIRMATION:  $y = 0.23299926 < t/d$

Calculation of ratio  $I_b / I_d$

Inadequate Lap Length with  $I_b / I_d = 0.30$

- Calculation of  $p$  -

From table 10-8:  $p = 0.042$

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.51791795$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00568407$

jacket:  $s_1 = A_{v1} * L_{stir1} / (s_1 * A_g) = 0.00301593$

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

$L_{stir1} = 2160.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} * L_{stir2} / (s_2 * A_g) = 0.00056047$

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

$L_{stir2} = 1568.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

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

where  $f = 2 * t_f / b_w$  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.

$N_{UD} = 22758.377$

$A_g = 562500.00$

$f_{cE} = (f_{c,jacket} * Area_{jacket} + f_{c,core} * Area_{core}) / section\_area = 33.00$

$f_{yIE} = (f_{y,ext\_Long\_Reinf} * Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} * Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 555.56$

$f_{yIE} = (f_{y,ext\_Trans\_Reinf} * s_1 + f_{y,int\_Trans\_Reinf} * s_2) / (s_1 + s_2) = 555.56$

$p_l = Area_{Tot\_Long\_Rein} / (b * d) = 0.00996292$

$b = 950.00$

$d = 707.00$

$f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 11

column C1, Floor 1

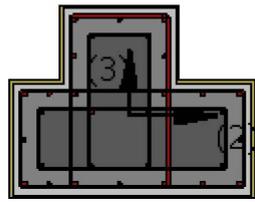
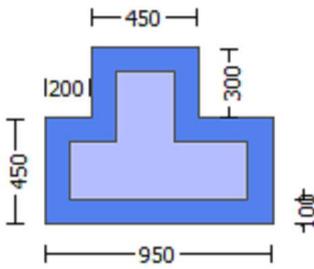
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjctcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Secondary 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

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $Ecc = 200.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary 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

Inadequate Lap Length with  $l_o/l_{o,min} = l_b/l_d = 0.30$

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,  $NoDir = 1$   
Fiber orientations,  $bi = 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties  
-----

EDGE -A-  
Bending Moment,  $M_a = -399933.566$   
Shear Force,  $V_a = 199.8573$   
EDGE -B-  
Bending Moment,  $M_b = -197954.378$   
Shear Force,  $V_b = -199.8573$   
BOTH EDGES  
Axial Force,  $F = -22758.377$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_{lt} = 0.00$   
-Compression:  $As_{lc} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{l,ten} = 2475.575$   
-Compression:  $As_{l,com} = 1539.38$   
-Middle:  $As_{l,mid} = 2676.637$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.72727$

-----  
New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 1.1019E+006$   
 $V_n ((10.3), ASCE 41-17) = knl \cdot V_{CoI} = 1.1019E+006$   
 $V_{CoI} = 1.1019E+006$   
 $knl = 1.00$   
 $displacement\_ductility\_demand = 0.00685751$

-----  
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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)  
 $M / Vd = 3.33516$   
 $M_u = 399933.566$   
 $V_u = 199.8573$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 22758.377$   
 $A_g = 337500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 842449.486$   
where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 753982.237$   
 $V_{s,j1} = 471238.898$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col_{j1} = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 282743.339$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col_{j2} = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 88467.249$   
 $V_{s,c1} = 88467.249$  is calculated for section web core, with:  
 $d = 440.00$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

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

$$s/d = 1.25$$

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

$f = 0.95$ , 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:  $\theta = b1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|), \text{ with:}$$

total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$

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

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

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 896810.169$$

$$b_w = 450.00$$

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  $\theta = 1.6712847E-005$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00243716 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 6.7046E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 2001.096$$

$$\text{From table 10.5, ASCE 41-17: } E_{eff} = \text{factor} * E_c * I_g = 1.8350E+014$$

$$\text{factor} = 0.30$$

$$A_g = 562500.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$$

$$N = 22758.377$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 6.1166E+014$$

Calculation of Yielding Moment  $M_y$

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

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

$$\text{flange width, } b = 950.00$$

$$\text{web width, } b_w = 450.00$$

$$\text{flange thickness, } t = 450.00$$

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

$$y_{\text{ten}} = 2.8728328E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$$

$$d = 707.00$$

$$y = 0.23388249$$

$$A = 0.01007179$$

$$B = 0.00604786$$

$$\text{with } p_t = 0.00368581$$

pc = 0.00229194  
pv = 0.00398517  
N = 22758.377  
b = 950.00  
" = 0.06082037  
y\_comp = 1.3500043E-005  
with fc\* (12.3, (ACI 440)) = 33.25688  
fc = 33.00  
fl = 0.43533893  
b = bmax = 950.00  
h = hmax = 750.00  
Ag = 0.5625  
g = pt + pc + pv = 0.00996292  
rc = 40.00  
Ae/Ac = 0.30198841  
Effective FRP thickness, tf = NL\*t\*cos(b1) = 1.016  
effective strain from (12.5) and (12.12), efe = 0.004  
fu = 0.01  
Ef = 64828.00  
Ec = 26999.444  
y = 0.23229755  
A = 0.0098865  
B = 0.00593898  
with Es = 200000.00  
CONFIRMATION: y = 0.23299926 < t/d

-----  
-----  
Calculation of ratio lb/d

-----  
Inadequate Lap Length with lb/d = 0.30

-----  
End Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 3

Integration Section: (a)  
-----

## Calculation No. 12

column C1, Floor 1

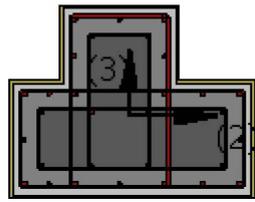
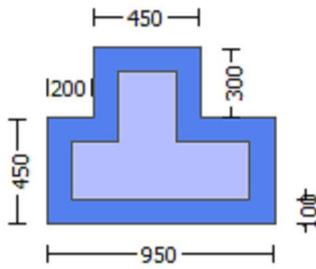
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( u)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $E_{cc} = 200.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.02437

Element Length,  $L = 3000.00$

Secondary 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

Inadequate Lap Length with  $l_o/l_{o,min} = 0.30$

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

At local axis: 3  
EDGE -A-  
Shear Force, Va = -4.9265533E-005  
EDGE -B-  
Shear Force, Vb = 4.9265533E-005  
BOTH EDGES  
Axial Force, F = -20792.019  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 6691.592  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 2475.575  
-Compression: Asl,com = 1539.38  
-Middle: Asl,mid = 2676.637

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.51791795$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 635124.647$   
with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 9.5269E+008$   
 $M_{u1+} = 9.5269E+008$ , 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  
 $M_{u1-} = 6.8428E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 9.5269E+008$   
 $M_{u2+} = 9.5269E+008$ , 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  
 $M_{u2-} = 6.8428E+008$ , 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:  
 $\phi_u = 8.7398457E-006$   
 $M_u = 9.5269E+008$

with full section properties:

$$b = 950.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093808$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01211878$$

$$\phi_u \text{ ((5.4c), TBDY)} = a_s e^* \text{ sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.04642716$$

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

$$\phi_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$$

$$b_{\text{max}} = 950.00$$

hmax = 750.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

fy = 0.03444474  
Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
af = 0.28545185  
with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$   
bmax = 950.00  
hmax = 750.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

R = 40.00  
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015

ase ((5.4d), TBDY) =  $(ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.53070105$

ase1 =  $Max(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $bi^2/6$  as defined at (A.2).

ase2 ( $\geq ase1$ ) =  $Max(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $bi^2/6$  as defined at (A.2).

$psh_{min}*Fy_{we} = Min(psh_x*Fy_{we}, psh_y*Fy_{we}) = 2.48363$

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

$psh_x*Fy_{we} = psh1*Fy_{we1} + ps2*Fy_{we2} = 2.48363$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00301593$   
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00056047$   
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

$psh_y*Fy_{we} = psh1*Fy_{we1} + ps2*Fy_{we2} = 2.97078$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00  
s1 = 100.00

$s_2 = 250.00$   
 $fy_{we1} = 694.45$   
 $fy_{we2} = 694.45$   
 $f_{ce} = 33.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $y_1 = 0.00140044$   
 $sh_1 = 0.0044814$   
 $ft_1 = 466.8167$   
 $fy_1 = 389.0139$   
 $su_1 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/d = 0.30$   
 $su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esu_1 \text{ nominal} = 0.08$ ,  
 For calculation of  $esu_1 \text{ nominal}$  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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$   
 with  $Es_1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$   
 $y_2 = 0.00140044$   
 $sh_2 = 0.0044814$   
 $ft_2 = 466.8167$   
 $fy_2 = 389.0139$   
 $su_2 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/lb, \min = 0.30$   
 $su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esu_2 \text{ nominal} = 0.08$ ,  
 For calculation of  $esu_2 \text{ nominal}$  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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 389.0139$   
 with  $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.00140044$   
 $sh_v = 0.0044814$   
 $ft_v = 466.8167$   
 $fy_v = 389.0139$   
 $suv = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/d = 0.30$   
 $suv = 0.4 * esuv \text{ nominal ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esuv \text{ nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv \text{ nominal}$  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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_v = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 389.0139$   
 with  $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / f_c) = 0.04344945$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / f_c) = 0.02701806$   
 $v = A_{sl,mid} / (b * d) * (fs_v / f_c) = 0.04697834$   
 and confined core properties:  
 $b = 890.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} \text{ (5A.2, TBDY)} = 33.80412$   
 $cc \text{ (5A.5, TBDY)} = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / f_c) = 0.04843381$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / f_c) = 0.03011747$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05236752$$

Case/Assumption: Unconfined full section - Steel rupture  
satisfies Eq. (4.3)

--->

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

--->

$$s_u(4.9) = 0.17139647$$

$$M_u = M_{Rc}(4.14) = 9.5269E+008$$

$$u = s_u(4.1) = 8.7398457E-006$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $M_{u1}$ -

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

$$u = 8.8144127E-006$$

$$M_u = 6.8428E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear\_factor} \cdot \text{Max}(\alpha, \alpha_c) = 0.01211878$$

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

$$\text{From (5.4b), TB DY: } \alpha_c = 0.01211878$$

$$\alpha_{we}((5.4c), \text{TB DY}) = \alpha_{se} \cdot \text{sh}_{, \min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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)

$$f_x = 0.03444474$$

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

$$\alpha_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$\alpha_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se}((5.4d), \text{TB DY}) = (\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.53070105$$

$$\alpha_{se1} = \text{Max}(((A_{conf, \max 1} - A_{noConf1}) / A_{conf, \max 1}) \cdot (A_{conf, \min 1} / A_{conf, \max 1}), 0) = 0.53070105$$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

-----  
 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1_{nominal}$  ((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  $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

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

$y2 = 0.00140044$

$sh_2 = 0.0044814$   
 $ft_2 = 466.8167$   
 $fy_2 = 389.0139$   
 $su_2 = 0.00512$   
 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  
 $lo/lo_{min} = lb/lb_{min} = 0.30$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 389.0139$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.00140044$   
 $shv = 0.0044814$   
 $ftv = 466.8167$   
 $fyv = 389.0139$   
 $suv = 0.00512$   
 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  
 $lo/lo_{min} = lb/ld = 0.30$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 389.0139$   
 with  $Esv = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.05703813$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.09172662$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.0991765$   
 and confined core properties:  
 $b = 390.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 33.80412$   
 $cc (5A.5, TBDY) = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.06872961$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.11052844$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.11950537$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.17840617$   
 $Mu = MRc (4.14) = 6.8428E+008$   
 $u = su (4.1) = 8.8144127E-006$

-----  
 Calculation of ratio  $lb/ld$   
 -----

Inadequate Lap Length with  $lb/ld = 0.30$   
 -----  
 -----

-----  
 Calculation of  $Mu_{2+}$   
 -----

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 8.7398457E-006$

Mu = 9.5269E+008

with full section properties:

b = 950.00

d = 707.00

d' = 43.00

v = 0.00093808

N = 20792.019

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01211878

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

From (5.4b), TBDY: cu = 0.01211878

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+ Min( fx, fy) = 0.04642716

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.03444474

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.28545185

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 160566.667

bmax = 950.00

hmax = 750.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

fy = 0.03444474

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.28545185

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 160566.667

bmax = 950.00

hmax = 750.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

R = 40.00

Effective FRP thickness, tf = NL\*t\*Cos(b1) = 1.016

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.53070105

ase1 = Max(((Aconf,max1-AnoConf1)/Aconf,max1)\*(Aconf,min1/Aconf,max1),0) = 0.53070105

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 = 464100.00 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 = 395025.00 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 = 174733.333 is the unconfined external core area which is equal to bi2/6 as defined at (A.2).

ase2 (>=ase1) = Max(((Aconf,max2-AnoConf2)/Aconf,max2)\*(Aconf,min2/Aconf,max2),0) = 0.53070105

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 = 252164.00 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 = 111441.00 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 = 112376.00 is the unconfined internal core area which is equal to bi2/6 as defined at (A.2).

psh,min\*Fywe = Min(psh,x\*Fywe, psh,y\*Fywe) = 2.48363

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

$psh_x \cdot Fy_{we} = psh1 \cdot Fy_{we1} + ps2 \cdot Fy_{we2} = 2.48363$   
 $psh1$  ((5.4d), TBDY) =  $Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.00301593$   
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00056047$   
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

$psh_y \cdot Fy_{we} = psh1 \cdot Fy_{we1} + ps2 \cdot Fy_{we2} = 2.97078$   
 $psh1$  ((5.4d), TBDY) =  $Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00  
s1 = 100.00  
s2 = 250.00  
fywe1 = 694.45  
fywe2 = 694.45  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367  
c = confinement factor = 1.02437

y1 = 0.00140044  
sh1 = 0.0044814  
ft1 = 466.8167  
fy1 = 389.0139  
su1 = 0.00512

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 = 0.30

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 =  $(fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 389.0139$

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

y2 = 0.00140044  
sh2 = 0.0044814  
ft2 = 466.8167  
fy2 = 389.0139  
su2 = 0.00512

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 = 0.30

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 =  $(fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 389.0139$

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

yv = 0.00140044  
shv = 0.0044814  
ftv = 466.8167  
fyv = 389.0139  
suv = 0.00512

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

$$l_0/l_{ou,min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$$

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

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv\_nominal}$  and  $\gamma_v$ ,  $sh_v, ft_v, fy_v$ , it is considered

characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$$\gamma_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from } 10.3.5, \text{ ASCE } 41-17.$$

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 389.0139$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.04344945$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.02701806$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.04697834$$

and confined core properties:

$$b = 890.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.80412$$

$$c_c (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.04843381$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.03011747$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.05236752$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.17139647$$

$$M_u = M_{Rc} (4.14) = 9.5269E+008$$

$$u = s_u (4.1) = 8.7398457E-006$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_2$ -

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

$$u = 8.8144127E-006$$

$$M_u = 6.8428E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, c_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.01211878$$

$$\text{we ((5.4c), TBDY) } = a_{se} * sh_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

fy = 0.03444474  
Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$   
af = 0.28545185  
with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 160566.667$   
bmax = 950.00  
hmax = 750.00  
From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00  
Effective FRP thickness,  $t_f = N_L * t * \cos(b_1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015

ase ((5.4d), TBDY) =  $(ase_1 * A_{ext} + ase_2 * A_{int})/A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

$A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$$fy_{we2} = 694.45$$

$$f_{ce} = 33.00$$

From ((5.A.5), TBDY), TBDY:  $cc = 0.00224367$

$$c = \text{confinement factor} = 1.02437$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

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

$$lo/lou, \min = lb/ld = 0.30$$

$$su_1 = 0.4 * esu_{1, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

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

For calculation of  $esu_{1, \text{nominal}}$  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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = (fs_{\text{jacket}} * Asl, \text{ten, jacket} + fs_{\text{core}} * Asl, \text{ten, core}) / Asl, \text{ten} = 389.0139$$

$$\text{with } Es_1 = (Es_{\text{jacket}} * Asl, \text{ten, jacket} + Es_{\text{core}} * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

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

$$lo/lou, \min = lb/lb, \min = 0.30$$

$$su_2 = 0.4 * esu_{2, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY:  $esu_{2, \text{nominal}} = 0.08$ ,

For calculation of  $esu_{2, \text{nominal}}$  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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_{\text{jacket}} * Asl, \text{com, jacket} + fs_{\text{core}} * Asl, \text{com, core}) / Asl, \text{com} = 389.0139$$

$$\text{with } Es_2 = (Es_{\text{jacket}} * Asl, \text{com, jacket} + Es_{\text{core}} * Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$suv = 0.00512$$

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

$$lo/lou, \min = lb/ld = 0.30$$

$$suv = 0.4 * esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

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  $y_v, sh_v, ft_v, fy_v$ , 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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs_{\text{jacket}} * Asl, \text{mid, jacket} + fs_{\text{mid}} * Asl, \text{mid, core}) / Asl, \text{mid} = 389.0139$$

$$\text{with } Es_v = (Es_{\text{jacket}} * Asl, \text{mid, jacket} + Es_{\text{mid}} * Asl, \text{mid, core}) / Asl, \text{mid} = 200000.00$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / f_c) = 0.05703813$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / f_c) = 0.09172662$$

$$v = Asl, \text{mid} / (b * d) * (fsv / f_c) = 0.0991765$$

and confined core properties:

$$b = 390.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, \text{TBDY}) = 33.80412$$

$$cc (5A.5, \text{TBDY}) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / f_c) = 0.06872961$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / f_c) = 0.11052844$$

$$v = Asl, \text{mid} / (b * d) * (fsv / f_c) = 0.11950537$$

Case/Assumption: Unconfinedsd full section - Steel rupture

satisfies Eq. (4.3)

--->

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

--->

$$\mu_u (4.9) = 0.17840617$$

$$\mu_u = M/R_c (4.14) = 6.8428E+008$$

$$u = \mu_u (4.1) = 8.8144127E-006$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.2263E+006$   
-----

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 1.2263E+006$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{ColO}$$

$$V_{ColO} = 1.2263E+006$$

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

-----  
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 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_c \text{ jacket} * \text{Area jacket} + f'_c \text{ core} * \text{Area core}) / \text{Area section} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)

$$M/d = 4.00$$

$$\mu_u = 7.32046$$

$$V_u = 4.9265533E-005$$

$$d = 0.8 * h = 600.00$$

$$N_u = 20792.019$$

$$A_g = 337500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 936062.473$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$$

$V_{s,j1} = 523602.964$  is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$$s/d = 0.16666667$$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.27777778$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.25$$

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

$f = 0.95$ , 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:  $\theta = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$ , 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:  $V_s + V_f \leq 1.0304E+006$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.2263E+006$

$V_{r2} = V_{Col}((10.3), \text{ASCE 41-17}) = k_{nl} * V_{Col0}$

$V_{Col0} = 1.2263E+006$

$k_{nl} = 1$  (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).

$\lambda = 1$  (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/d = 4.00$

$\mu_u = 7.3142$

$V_u = 4.9265533E-005$

$d = 0.8 * h = 600.00$

$N_u = 20792.019$

$A_g = 337500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 936062.473$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$

$V_{s,j1} = 523602.964$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $Col_{j1} = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $Col_{j2} = 1.00$

$s/d = 0.27777778$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col_{c1} = 1.00$

$s/d = 0.56818182$

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

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col_{c2} = 0.00$

s/d = 1.25

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 + cota) sina which is more a generalised expression, where 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° and = -45° to take into consideration the cyclic seismic loading.

orientation 1: 1 = b1 + 90° = 90.00

Vf = Min(|Vf(45, 1)|, |Vf(-45,a1)|), with:

total thickness per orientation, tf1 = NL\*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 <= 1.0304E+006

bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjtcs

Constant Properties

Knowledge Factor, = 1.00

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

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, fc = fcm = 33.00

New material of Secondary Member: Steel Strength, fs = fsm = 555.56

Concrete Elasticity, Ec = 26999.444

Steel Elasticity, Es = 200000.00

Existing Column

New material of Secondary Member: Concrete Strength, fc = fcm = 33.00

New material of Secondary Member: Steel Strength, fs = fsm = 555.56

Concrete Elasticity, Ec = 26999.444

Steel Elasticity, Es = 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, fs = 1.25\*fsm = 694.45

Existing Column

New material: Steel Strength, fs = 1.25\*fsm = 694.45

#####

Max Height, Hmax = 750.00

Min Height, Hmin = 450.00

Max Width, Wmax = 950.00

Min Width, Wmin = 450.00

Eccentricity, Ecc = 200.00

Jacket Thickness, tj = 100.00

Cover Thickness, c = 25.00

Mean Confinement Factor overall section = 1.02437

Element Length, L = 3000.00

Secondary 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

Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$

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: 2

EDGE -A-

Shear Force,  $V_a = 0.00030591$

EDGE -B-

Shear Force,  $V_b = -0.00030591$

BOTH EDGES

Axial Force,  $F = -20792.019$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 0.00$

-Compression:  $A_{sl,c} = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 2682.92$

-Compression:  $A_{sl,com} = 1539.38$

-Middle:  $A_{sl,mid} = 2469.292$

-----  
-----  
Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.55437584$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 860817.439$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.2912E+009$

$M_{u1+} = 1.2912E+009$ , 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

$M_{u1-} = 8.6158E+008$ , 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.2912E+009$

$M_{u2+} = 1.2912E+009$ , 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

$M_{u2-} = 8.6158E+008$ , 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:

$\phi_u = 7.0548964E-006$

$M_u = 1.2912E+009$

-----  
with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.019$

$f_c = 33.00$

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

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$

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

From (5.4b), TBDY:  $c_u = 0.01211878$

$w_e$  ((5.4c), TBDY) =  $a_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

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

-----  
 $f_x = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $f_y = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $R = 40.00$

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), TBDY) =  $(a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$

$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53070105$

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.

$A_{\text{conf,max2}} = 252164.00$  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.

$A_{\text{conf,min2}} = 111441.00$  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.

$A_{\text{noConf2}} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00357443  
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00070345  
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367

c = confinement factor = 1.02437

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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 = 0.30

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/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.07748884

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.04446081$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07131877$$

and confined core properties:

$$b = 390.00$$

$$d = 877.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.80412$$

$$c_c (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0924687$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.05305581$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08510586$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.19984886$$

$$\mu_u = M_{Rc} (4.14) = 1.2912E+009$$

$$u = s_u (4.1) = 7.0548964E-006$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u1}$ -

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

$$u = 6.7307746E-006$$

$$\mu_u = 8.6158E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01211878$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00  
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

$A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c =$  confinement factor = 1.02437

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04446081

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07748884

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.07131877

and confined core properties:

b = 390.00

d = 877.00

d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.05305581

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0924687

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.08510586

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16131742

Mu = MRc (4.14) = 8.6158E+008

u = su (4.1) = 6.7307746E-006

-----  
Calculation of ratio lb/d

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{2+}$

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

$$\mu = 7.0548964E-006$$

$$\mu_u = 1.2912E+009$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.01211878$$

$$\mu_{ve} \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{, \text{min}} * f_{yve} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$$

$$b_{\text{max}} = 950.00$$

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

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

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

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$$

$$b_{\text{max}} = 950.00$$

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

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (> a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53070105$$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

-----  
 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c =$  confinement factor = 1.02437

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1_{nominal}$  ((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  $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

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

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$

$su2 = 0.4 * esu2_{nominal}$  ((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.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = (fs_{jacket} \cdot A_{s1,com,jacket} + fs_{core} \cdot A_{s1,com,core}) / A_{s1,com} = 389.0139$

with  $Es_2 = (Es_{jacket} \cdot A_{s1,com,jacket} + Es_{core} \cdot A_{s1,com,core}) / A_{s1,com} = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$suv = 0.00512$

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

$l_o/l_{o,min} = l_b/l_d = 0.30$

$suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

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  $fsv = (fs_{jacket} \cdot A_{s,mid,jacket} + fs_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 389.0139$

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

$1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.07748884$

$2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04446081$

$v = A_{s,mid} / (b \cdot d) \cdot (fsv / fc) = 0.07131877$

and confined core properties:

$b = 390.00$

$d = 877.00$

$d' = 13.00$

$fcc$  (5A.2, TBDY) = 33.80412

$cc$  (5A.5, TBDY) = 0.00224367

$c$  = confinement factor = 1.02437

$1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0924687$

$2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05305581$

$v = A_{s,mid} / (b \cdot d) \cdot (fsv / fc) = 0.08510586$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su$  (4.9) = 0.19984886

$Mu = MRc$  (4.14) = 1.2912E+009

$u = su$  (4.1) = 7.0548964E-006

-----  
Calculation of ratio  $l_b/l_d$

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Inadequate Lap Length with  $l_b/l_d = 0.30$   
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-----  
Calculation of  $Mu_2$ -  
-----  
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-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 6.7307746E-006$

$Mu = 8.6158E+008$   
-----

with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.019$

$fc = 33.00$

$co$  (5A.5, TBDY) = 0.002

Final value of  $cu$ :  $cu^* = \text{shear\_factor} \cdot \text{Max}(cu, cc) = 0.01211878$

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

From (5.4b), TBDY:  $c_u = 0.01211878$

$w_e$  ((5.4c), TBDY) =  $a_{se} \cdot s_{h,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

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)

$f_x = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.03444474$

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

$a_f = 0.28545185$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se}$  ((5.4d), TBDY) =  $(a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int})/A_{sec} = 0.53070105$

$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) \cdot (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$a_{se2} (\geq a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) \cdot (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 2.48363$

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)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$p_{sh2}$  (5.4d) =  $L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 2.97078$

psh1 ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367

c = confinement factor = 1.02437

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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 = 0.30

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 =  $(fs\_jacket * A_{sl,ten,jacket} + fs\_core * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

with Es1 =  $(Es\_jacket * A_{sl,ten,jacket} + Es\_core * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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 =  $(fs\_jacket * A_{sl,com,jacket} + fs\_core * A_{sl,com,core}) / A_{sl,com} = 389.0139$

with Es2 =  $(Es\_jacket * A_{sl,com,jacket} + Es\_core * A_{sl,com,core}) / A_{sl,com} = 200000.00$

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv =  $(fs\_jacket * A_{sl,mid,jacket} + fs\_mid * A_{sl,mid,core}) / A_{sl,mid} = 389.0139$

with Esv =  $(Es\_jacket * A_{sl,mid,jacket} + Es\_mid * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$

1 =  $A_{sl,ten} / (b * d) * (fs1 / fc) = 0.04446081$

2 =  $A_{sl,com} / (b * d) * (fs2 / fc) = 0.07748884$

v =  $A_{sl,mid} / (b * d) * (fsv / fc) = 0.07131877$

and confined core properties:

$$b = 390.00$$

$$d = 877.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.80412$$

$$cc (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05305581$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.0924687$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08510586$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16131742$$

$$\mu = MR_c (4.14) = 8.6158E+008$$

$$u = s_u (4.1) = 6.7307746E-006$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.5528E+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.5528E+006$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$

$$V_{Col0} = 1.5528E+006$$

$k_{nl} = 1$  (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:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 57.90343$$

$$V_u = 0.00030591$$

$$d = 0.8 * h = 760.00$$

$$N_u = 20792.019$$

$$A_g = 427500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$$

where:

$$V_{s,jacket} = V_{sj1} + V_{sj2} = 977392.20$$

$V_{sj1} = 314161.779$  is calculated for section web jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{sj1}$  is multiplied by  $Col_{j1} = 1.00$

$$s/d = 0.27777778$$

$V_{sj2} = 663230.422$  is calculated for section flange jacket, with:

$$d = 760.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{sj2}$  is multiplied by  $Col_{j2} = 1.00$

$$s/d = 0.13157895$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 477918.239

$f = 0.95$ , 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  $\theta$  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:  $\theta = b_1 + 90^\circ = 90.00$

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

total thickness per orientation,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 907.00

$f_{fe}$  ((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:  $V_s + V_f \leq 1.3051E+006$

$bw = 450.00$

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 1.5528E+006$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Col0}$

$V_{Col0} = 1.5528E+006$

$k_{nl} = 1$  (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).

-----  
 $\gamma_c = 1$  (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/d = 4.00$

$\mu_u = 57.90455$

$V_u = 0.00030591$

$d = 0.8 \cdot h = 760.00$

$N_u = 20792.019$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$

where:

$V_{s,jacket} = V_{sj1} + V_{sj2} = 977392.20$

$V_{sj1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{sj1}$  is multiplied by  $Col,j1 = 1.00$

$s/d = 0.27777778$

$V_{sj2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{sj2}$  is multiplied by  $Col,j2 = 1.00$

$s/d = 0.13157895$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$

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

$d = 200.00$

Av = 100530.965

fy = 555.56

s = 250.00

Vs,c1 is multiplied by Col,c1 = 0.00

s/d = 1.25

Vs,c2 = 134042.359 is calculated for section flange core, with:

d = 600.00

Av = 100530.965

fy = 555.56

s = 250.00

Vs,c2 is multiplied by Col,c2 = 1.00

s/d = 0.41666667

Vf ((11-3)-(11.4), ACI 440) = 477918.239

f = 0.95, for fully-wrapped sections

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

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

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

orientation 1:  $\theta = 45^\circ$

Vf = Min(|Vf(45,  $\alpha_1$ )|, |Vf(-45,  $\alpha_1$ )|), with:

total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$

dfv = d (figure 11.2, ACI 440) = 907.00

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 <= 1.3051E+006

bw = 450.00

-----  
End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 2

-----  
Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
At local axis: 3  
Integration Section: (a)  
Section Type: rcjtcs

Constant Properties

-----  
Knowledge Factor,  $\phi = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $Ecc = 200.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary 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  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
 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

-----  
 Bending Moment,  $M = -2.9466E+007$   
 Shear Force,  $V_2 = -9672.998$   
 Shear Force,  $V_3 = 199.8573$   
 Axial Force,  $F = -22758.377$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $As_{lt} = 0.00$   
 -Compression:  $As_{lc} = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten} = 2682.92$   
 -Compression:  $As_{l,com} = 1539.38$   
 -Middle:  $As_{l,mid} = 2469.292$   
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten,jacket} = 2375.044$   
 -Compression:  $As_{l,com,jacket} = 1231.504$   
 -Middle:  $As_{l,mid,jacket} = 1545.664$   
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten,core} = 307.8761$   
 -Compression:  $As_{l,com,core} = 307.8761$   
 -Middle:  $As_{l,mid,core} = 923.6282$   
 Mean Diameter of Tension Reinforcement,  $DbL = 17.45455$

-----  
 New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.04516375$   
 $u = y + p = 0.04516375$

-----  
 - Calculation of  $y$  -

-----  
 $y = (M_y * L_s / 3) / E_{eff} = 0.00316375$  ((4.29), Biskinis Phd))  
 $M_y = 8.7538E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3046.206  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.8095E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 22758.377$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.3651E+014$

-----  
 Calculation of Yielding Moment  $M_y$

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

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

$y_{ten} = 2.3929630E-006$   
 with  $((10.1), ASCE 41-17) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/l_d)^{2/3}) = 311.2112$   
 $d = 907.00$   
 $y = 0.28306153$   
 $A = 0.0165741$   
 $B = 0.01009974$   
 with  $pt = 0.00657337$   
 $pc = 0.0037716$   
 $pv = 0.00604996$   
 $N = 22758.377$   
 $b = 450.00$   
 $" = 0.04740904$

$y_{comp} = 8.6873791E-006$   
 with  $f_c^* (12.3, (ACI 440)) = 33.253$   
 $f_c = 33.00$   
 $f_l = 0.43533893$   
 $b = b_{max} = 950.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.5625$   
 $g = pt + pc + pv = 0.01639493$   
 $rc = 40.00$   
 $A_e/A_c = 0.29742395$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.28135356$   
 $A = 0.01626917$   
 $B = 0.00992057$   
 with  $E_s = 200000.00$

-----  
 Calculation of ratio  $l_b/l_d$   
 -----

Inadequate Lap Length with  $l_b/l_d = 0.30$   
 -----

- Calculation of  $p$  -  
 -----

From table 10-8:  $p = 0.042$

with:

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

shear control ratio  $V_y E / V_{CoI} O E = 0.55437584$

$d = d_{external} = 907.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00638555$

jacket:  $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.00357443$

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

$L_{stir1} = 2560.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00070345$

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

$L_{stir2} = 1968.00$ , 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.

$NUD = 22758.377$

$A_g = 562500.00$

$f_c E = (f_c \cdot \text{jacket} \cdot \text{Area}_{jacket} + f_c \cdot \text{core} \cdot \text{Area}_{core}) / \text{section\_area} = 33.00$

$f_y E = (f_y \cdot \text{ext\_Long\_Reinf} \cdot \text{Area}_{ext\_Long\_Reinf} + f_y \cdot \text{int\_Long\_Reinf} \cdot \text{Area}_{int\_Long\_Reinf}) / \text{Area}_{Tot\_Long\_Rein} = 555.56$

$f_y E = (f_y \cdot \text{ext\_Trans\_Reinf} \cdot s_1 + f_y \cdot \text{int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$

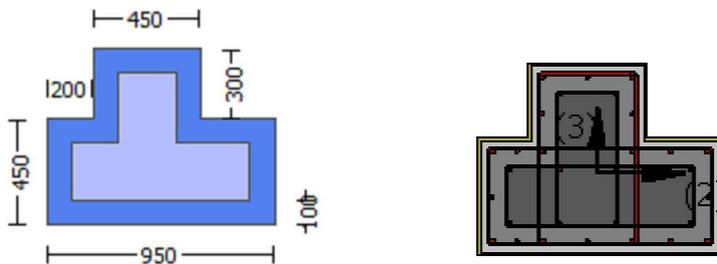
$p_l = \text{Area}_{Tot\_Long\_Rein} / (b \cdot d) = 0.01639493$

b = 450.00  
d = 907.00  
f<sub>cE</sub> = 33.00

End Of Calculation of Chord Rotation Capacity for element: column JTC1 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 VR<sub>d</sub>  
Edge: End  
Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1  
At local axis: 2  
Integration Section: (b)  
Section Type: rcjtcs

Constant Properties

Knowledge Factor, = 1.00  
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 Secondary Member: Concrete Strength, f<sub>c</sub> = f<sub>c\_lower\_bound</sub> = 25.00  
New material of Secondary Member: Steel Strength, f<sub>s</sub> = f<sub>s\_lower\_bound</sub> = 500.00  
Concrete Elasticity, E<sub>c</sub> = 26999.444  
Steel Elasticity, E<sub>s</sub> = 200000.00  
Existing Column

New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
 Concrete Elasticity,  $E_c = 26999.444$   
 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  
 New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 450.00$   
 Max Width,  $W_{max} = 950.00$   
 Min Width,  $W_{min} = 450.00$   
 Eccentricity,  $Ecc = 200.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary 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  
 Inadequate Lap Length with  $l_o/l_{o,min} = l_b/l_d = 0.30$   
 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,  $M_a = -2.9466E+007$   
 Shear Force,  $V_a = -9672.998$   
 EDGE -B-  
 Bending Moment,  $M_b = 440405.491$   
 Shear Force,  $V_b = 9672.998$   
 BOTH EDGES  
 Axial Force,  $F = -22758.377$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $As_t = 0.00$   
 -Compression:  $As_c = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten} = 2682.92$   
 -Compression:  $As_{l,com} = 1539.38$   
 -Middle:  $As_{l,mid} = 2469.292$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.45455$   
 -----  
 -----

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 * V_n = 1.5680E+006$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI} = 1.5680E+006$   
 $V_{CoI} = 1.5680E+006$

knl = 1.00  
displacement\_ductility\_demand = 0.05200836

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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 440405.491$

$V_u = 9672.998$

$d = 0.8 \cdot h = 760.00$

$N_u = 22758.377$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 1.0003\text{E}+006$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 879645.943$

$V_{s,j1} = 282743.339$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $\text{Col},j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 596902.604$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $\text{Col},j2 = 1.00$

$s/d = 0.13157895$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 120637.158$

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

$d = 200.00$

$A_v = 100530.965$

$f_y = 500.00$

$s = 250.00$

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

$s/d = 1.25$

$V_{s,c2} = 120637.158$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 500.00$

$s = 250.00$

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

$s/d = 0.41666667$

$V_f$  ((11-3)-(11.4), ACI 440) = 477918.239

$f = 0.95$ , 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) = 907.00

$f_{fe}$  ((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:  $V_s + V_f \leq 1.1360\text{E}+006$

$b_w = 450.00$

displacement ductility demand is calculated as  $\phi / y$

- Calculation of  $\phi / y$  for END B -  
for rotation axis 3 and integ. section (b)

-----  
From analysis, chord rotation  $\theta = 1.6204565E-005$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00031158$  ((4.29), Biskinis Phd)  
 $M_y = 8.7538E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.8095E+014$   
factor = 0.30  
 $A_g = 562500.00$   
Mean concrete strength:  $f'_c = (f'_{c\_jacket} * Area\_jacket + f'_{c\_core} * Area\_core) / Area\_section = 33.00$   
 $N = 22758.377$   
 $E_c * I_g = E_{c\_jacket} * I_{g\_jacket} + E_{c\_core} * I_{g\_core} = 9.3651E+014$   
-----  
-----

Calculation of Yielding Moment  $M_y$

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

-----  
 $y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 2.3929630E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 311.2112$   
 $d = 907.00$   
 $y = 0.28306153$   
 $A = 0.0165741$   
 $B = 0.01009974$   
with  $pt = 0.00657337$   
 $pc = 0.0037716$   
 $pv = 0.00604996$   
 $N = 22758.377$   
 $b = 450.00$   
 $" = 0.04740904$   
 $y_{comp} = 8.6873791E-006$   
with  $f'_c$  (12.3, (ACI 440)) = 33.253  
 $f_c = 33.00$   
 $f_l = 0.43533893$   
 $b = b_{max} = 950.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.5625$   
 $g = pt + pc + pv = 0.01639493$   
 $rc = 40.00$   
 $A_e / A_c = 0.29742395$   
Effective FRP thickness,  $t_f = N L * t * \text{Cos}(\theta) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.28135356$   
 $A = 0.01626917$   
 $B = 0.00992057$   
with  $E_s = 200000.00$   
-----  
-----

Calculation of ratio  $l_b / l_d$

Inadequate Lap Length with  $l_b / l_d = 0.30$

End Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (b)

-----  
-----

## Calculation No. 14

column C1, Floor 1

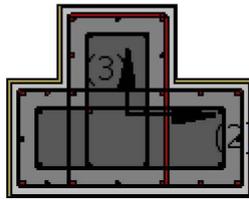
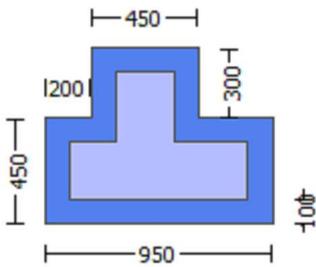
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

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

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

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $Ecc = 200.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.02437  
Element Length,  $L = 3000.00$   
Secondary 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  
Inadequate Lap Length with  $l_o/l_{o,min} = 0.30$   
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,  $V_a = -4.9265533E-005$   
EDGE -B-  
Shear Force,  $V_b = 4.9265533E-005$   
BOTH EDGES  
Axial Force,  $F = -20792.019$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 2475.575$   
-Compression:  $As_{l,com} = 1539.38$   
-Middle:  $As_{l,mid} = 2676.637$

-----  
Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.51791795$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 635124.647$   
with  
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 9.5269E+008$   
 $Mu_{1+} = 9.5269E+008$ , 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  
 $Mu_{1-} = 6.8428E+008$ , 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  
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 9.5269E+008$   
 $Mu_{2+} = 9.5269E+008$ , 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  
 $Mu_{2-} = 6.8428E+008$ , 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  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

u = 8.7398457E-006  
Mu = 9.5269E+008

with full section properties:

b = 950.00  
d = 707.00  
d' = 43.00  
v = 0.00093808  
N = 20792.019  
fc = 33.00  
co (5A.5, TBDY) = 0.002

Final value of cu:  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01211878$

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

From (5.4b), TBDY:  $cu = 0.01211878$

we ((5.4c), TBDY) =  $ase * sh, \min * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.04642716$

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

$fx = 0.03444474$

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

$af = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A 4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff,e = 881.8461$

$fy = 0.03444474$

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

$af = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A 4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff,e = 881.8461$

R = 40.00

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53070105$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $bi^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $bi^2/6$  as defined at (A.2).

$$psh_{min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 2.48363$$

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

$$psh_x * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 2.48363$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00301593$$

$$Lstir1 \text{ (Length of stirrups along Y)} = 2160.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00056047$$

$$Lstir2 \text{ (Length of stirrups along Y)} = 1568.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$psh_y * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 2.97078$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00357443$$

$$Lstir1 \text{ (Length of stirrups along X)} = 2560.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$$

$$Lstir2 \text{ (Length of stirrups along X)} = 1968.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$Asec = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

$$lo/lou_{min} = lb/ld = 0.30$$

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

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.

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

$$\text{with } fs1 = (fs_{jacket} * Asl_{ten,jacket} + fs_{core} * Asl_{ten,core}) / Asl_{ten} = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

$$lo/lou_{min} = lb/lb_{min} = 0.30$$

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

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.

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

$$\text{with } fs2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 389.0139$$

$$\text{with } Es2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$su_v = 0.00512$$

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fsjacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04344945

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.02701806

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.04697834

and confined core properties:

b = 890.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04843381

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.03011747

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.05236752

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

v < vs,y2 - LHS eq.(4.5) is satisfied

---->

su (4.9) = 0.17139647

Mu = MRc (4.14) = 9.5269E+008

u = su (4.1) = 8.7398457E-006

-----  
Calculation of ratio lb/ld

-----  
Inadequate Lap Length with lb/ld = 0.30  
-----  
-----  
-----

-----  
Calculation of Mu1-  
-----  
-----  
-----

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 8.8144127E-006

Mu = 6.8428E+008  
-----

with full section properties:

b = 450.00

d = 707.00

d' = 43.00

v = 0.00198039

N = 20792.019

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01211878

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

From (5.4b), TBDY: cu = 0.01211878

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.04642716

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.03444474

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.28545185

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 160566.667

bmax = 950.00

hmax = 750.00

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $ff,e = 881.8461$

$fy = 0.03444474$

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

$af = 0.28545185$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff,e = 881.8461$

$R = 40.00$

Effective FRP thickness,  $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_u,f = 1055.00$

$E_f = 64828.00$

$u,f = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.53070105$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $bi^2/6$  as defined at (A.2).

$ase2$  ( $\geq ase1$ ) =  $\text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $bi^2/6$  as defined at (A.2).

$psh_{min}*F_{ywe} = \text{Min}(psh_x*F_{ywe}, psh_y*F_{ywe}) = 2.48363$

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)

$psh_x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.48363$

$psh1$  ((5.4d), TBDY) =  $L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$psh2$  (5.4d) =  $L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

$psh_y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.97078$

$psh1$  ((5.4d), TBDY) =  $L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$psh2$  ((5.4d), TBDY) =  $L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

$A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

fywe1 = 694.45  
fywe2 = 694.45  
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00224367  
c = confinement factor = 1.02437

y1 = 0.00140044  
sh1 = 0.0044814  
ft1 = 466.8167  
fy1 = 389.0139  
su1 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044  
sh2 = 0.0044814  
ft2 = 466.8167  
fy2 = 389.0139  
su2 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044  
shv = 0.0044814  
ftv = 466.8167  
fyv = 389.0139  
suv = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.05703813

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09172662

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.0991765

and confined core properties:

b = 390.00  
d = 677.00  
d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.06872961

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.11052844

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.11950537

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) = 0.17840617

$M_u = M_{Rc}$  (4.14) = 6.8428E+008

$u = s_u$  (4.1) = 8.8144127E-006

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----

-----  
Calculation of  $M_{u2+}$   
-----  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 8.7398457E-006$

$M_u = 9.5269E+008$   
-----

with full section properties:

$b = 950.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093808$

$N = 20792.019$

$f_c = 33.00$

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

Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01211878$

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

From (5.4b), TBDY:  $\alpha = 0.01211878$

$\omega$  ((5.4c), TBDY) =  $\alpha * \text{sh\_min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

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

-----  
 $f_x = 0.03444474$

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

$\alpha_f = 0.28545185$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 160566.667$

$b_{\text{max}} = 950.00$

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

From EC8 A 4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$   
-----

$f_y = 0.03444474$

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

$\alpha_f = 0.28545185$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 160566.667$

$b_{\text{max}} = 950.00$

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

From EC8 A 4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$   
-----

$R = 40.00$

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) =  $(\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.53070105$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

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)

-----  
 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

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

$psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

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

-----  
 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

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

$psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

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

-----  
 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

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

$lo/lo_{u,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1\_nominal$  ((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  $fs1 = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 389.0139$

with  $Es1 = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

$y2 = 0.00140044$

$sh2 = 0.0044814$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 389.0139$$

$$\text{with } Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

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

$$lo/lou,min = lb/ld = 0.30$$

$$suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$$

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  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 389.0139$$

$$\text{with } Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.043444945$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.02701806$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.04697834$$

and confined core properties:

$$b = 890.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.80412$$

$$cc (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.04843381$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.03011747$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.05236752$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < vs,y2$  - LHS eq.(4.5) is satisfied

---->

$$su (4.9) = 0.17139647$$

$$Mu = MRc (4.14) = 9.5269E+008$$

$$u = su (4.1) = 8.7398457E-006$$

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 8.8144127E-006$$

$$Mu = 6.8428E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.019$$

$$f_c = 33.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01211878$$

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

$$\text{From (5.4b), TBDY: } \alpha = 0.01211878$$

$$\omega_e ((5.4c), TBDY) = \alpha_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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

$$f_x = 0.03444474$$

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

$$\alpha_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.03444474$$

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

$$\alpha_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

$$f_u, f = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.53070105$$

$$\alpha_{se1} = \text{Max}(((A_{conf, \max 1} - A_{noConf1}) / A_{conf, \max 1}) * (A_{conf, \min 1} / A_{conf, \max 1}), 0) = 0.53070105$$

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.

$A_{conf, \max 1} = 464100.00$  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.

$A_{conf, \min 1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{conf, \max 2} - A_{noConf2}) / A_{conf, \max 2}) * (A_{conf, \min 2} / A_{conf, \max 2}), 0) = 0.53070105$$

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.

$A_{conf, \max 2} = 252164.00$  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.

$A_{conf, \min 2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\rho_{sh, \min} * f_{ywe} = \text{Min}(\rho_{sh, x} * f_{ywe}, \rho_{sh, y} * f_{ywe}) = 2.48363$$

Expression (5.4d) for  $\rho_{sh, \min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without

earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.48363  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00301593  
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
psh2 (5.4d) = Lstir2\*Astir2/(Asec\*s2) = 0.00056047  
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00357443  
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00070345  
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367

c = confinement factor = 1.02437

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

$$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = (fs\_jacket * Asl\_mid\_jacket + fs\_mid * Asl\_mid\_core) / Asl\_mid = 389.0139$$

$$\text{with } Esv = (Es\_jacket * Asl\_mid\_jacket + Es\_mid * Asl\_mid\_core) / Asl\_mid = 200000.00$$

$$1 = Asl\_ten / (b * d) * (fs1 / fc) = 0.05703813$$

$$2 = Asl\_com / (b * d) * (fs2 / fc) = 0.09172662$$

$$v = Asl\_mid / (b * d) * (fsv / fc) = 0.0991765$$

and confined core properties:

$$b = 390.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.80412$$

$$cc (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = Asl\_ten / (b * d) * (fs1 / fc) = 0.06872961$$

$$2 = Asl\_com / (b * d) * (fs2 / fc) = 0.11052844$$

$$v = Asl\_mid / (b * d) * (fsv / fc) = 0.11950537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$  - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.17840617$$

$$Mu = MRc (4.14) = 6.8428E+008$$

$$u = su (4.1) = 8.8144127E-006$$

Calculation of ratio  $lb/ld$

Inadequate Lap Length with  $lb/ld = 0.30$

Calculation of Shear Strength  $Vr = Min(Vr1, Vr2) = 1.2263E+006$

Calculation of Shear Strength at edge 1,  $Vr1 = 1.2263E+006$

$Vr1 = VCol ((10.3), ASCE 41-17) = knl * VCol0$

$$VCol0 = 1.2263E+006$$

$knl = 1$  (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:  $fc' = (fc'_jacket * Area\_jacket + fc'_core * Area\_core) / Area\_section = 33.00$ , but  $fc'^{0.5} <= 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$Mu = 7.32046$$

$$Vu = 4.9265533E-005$$

$$d = 0.8 * h = 600.00$$

$$Nu = 20792.019$$

$$Ag = 337500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } Vs = Vs\_jacket + Vs\_core = 936062.473$$

where:

$$Vs\_jacket = Vs\_j1 + Vs\_j2 = 837764.743$$

$Vs\_j1 = 523602.964$  is calculated for section web jacket, with:

$$d = 600.00$$

$$Av = 157079.633$$

$$fy = 555.56$$

$$s = 100.00$$

$Vs\_j1$  is multiplied by  $Col\_j1 = 1.00$

$$s/d = 0.16666667$$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.27777778$$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.25$$

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

$f = 0.95$ , for fully-wrapped sections

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

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

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

orientation 1:  $\theta = b1 + 90^\circ = 90.00$

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

total thickness per orientation,  $t_{f1} = NL * t / NoDir = 1.016$

$df_v = d$  (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:  $V_s + V_f \leq 1.0304E+006$

$$bw = 450.00$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.2263E+006$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$

$$V_{Col0} = 1.2263E+006$$

$k_{nl} = 1$  (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).

$\lambda = 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 7.3142$$

$$V_u = 4.9265533E-005$$

$$d = 0.8 * h = 600.00$$

$$N_u = 20792.019$$

$$A_g = 337500.00$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 936062.473$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$$

$V_{s,j1} = 523602.964$  is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$$s/d = 0.16666667$$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.27777778$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.25$$

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

$f = 0.95$ , 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:  $\theta = b1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|), \text{ with:}$$

total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$

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

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

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 1.0304E+006$$

$$b_w = 450.00$$

-----  
End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 3

-----  
Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjtcs

Constant Properties

$$\text{Knowledge Factor, } \phi = 1.00$$

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

Consequently:

Jacket

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

$$\text{New material of Secondary Member: Steel Strength, } f_s = f_{sm} = 555.56$$

$$\text{Concrete Elasticity, } E_c = 26999.444$$

$$\text{Steel Elasticity, } E_s = 200000.00$$

Existing Column

$$\text{New material of Secondary Member: Concrete Strength, } f_c = f_{cm} = 33.00$$

$$\text{New material of Secondary Member: Steel Strength, } f_s = f_{sm} = 555.56$$

$$\text{Concrete Elasticity, } E_c = 26999.444$$

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  
New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $Ecc = 200.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.02437  
Element Length,  $L = 3000.00$   
Secondary 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  
Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$   
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: 2  
EDGE -A-  
Shear Force,  $V_a = 0.00030591$   
EDGE -B-  
Shear Force,  $V_b = -0.00030591$   
BOTH EDGES  
Axial Force,  $F = -20792.019$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 2682.92$   
-Compression:  $A_{sl,com} = 1539.38$   
-Middle:  $A_{sl,mid} = 2469.292$

-----  
-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.55437584$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 860817.439$   
with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.2912E+009$   
 $M_{u1+} = 1.2912E+009$ , 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  
 $M_{u1-} = 8.6158E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.2912E+009$

Mu2+ = 1.2912E+009, 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

Mu2- = 8.6158E+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 Mu1+  
-----

-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 7.0548964E-006$$

$$Mu = 1.2912E+009$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01211878$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03444474$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53070105$$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$$

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)

---

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2160.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1568.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

---

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.97078$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2560.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1968.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

---

$$A_{sec} = 562500.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.30$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{nominal} = 0.08,$$

For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 389.0139$$

$$\text{with } Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$$

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$$

$$su2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_{nominal} = 0.08,$$

For calculation of  $esu2_{nominal}$  and  $y2, sh2, ft2, fy2$ , it is considered

characteristic value  $f_{sy2} = f_{s2}/1.2$ , 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  $f_{s2} = (f_{s,jacket} \cdot A_{s1,com,jacket} + f_{s,core} \cdot A_{s1,com,core})/A_{s1,com} = 389.0139$

with  $E_{s2} = (E_{s,jacket} \cdot A_{s1,com,jacket} + E_{s,core} \cdot A_{s1,com,core})/A_{s1,com} = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$s_{uv} = 0.00512$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$s_{uv} = 0.4 \cdot e_{suv,nominal} ((5.5), TBDY) = 0.032$

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  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 389.0139$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.07748884$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.04446081$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07131877$

and confined core properties:

$b = 390.00$

$d = 877.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 33.80412$

$cc (5A.5, TBDY) = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0924687$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.05305581$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08510586$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$\mu_u (4.9) = 0.19984886$

$\mu_u = M/R_c (4.14) = 1.2912E+009$

$u = \mu_u (4.1) = 7.0548964E-006$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
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Calculation of  $\mu_{u1}$ -  
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-----  
Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 6.7307746E-006$

$\mu_u = 8.6158E+008$

-----  
with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.019$

$f_c = 33.00$

$cc (5A.5, TBDY) = 0.002$

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} \cdot \text{Max}( \mu_u, cc ) = 0.01211878$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.01211878$

we ((5.4c), TBDY) =  $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

where  $f = af * pf * ff_e / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.03444474$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.28545185$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf / bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff_e = 881.8461$

-----  
 $f_y = 0.03444474$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.28545185$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf / bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff_e = 881.8461$

-----  
 $R = 40.00$

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.53070105$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2$  ( $\geq ase1$ ) =  $\text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.48363$

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)

-----  
 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.48363$

$psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 2.97078  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00357443  
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00070345  
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367

c = confinement factor = 1.02437

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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 = 0.30

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/d)^2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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/d)^2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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/d)^2/3), from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04446081

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07748884

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07131877$$

and confined core properties:

$$b = 390.00$$

$$d = 877.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.80412$$

$$c_c (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05305581$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.0924687$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08510586$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16131742$$

$$\mu_u = M R_c (4.14) = 8.6158E+008$$

$$u = s_u (4.1) = 6.7307746E-006$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u2+}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 7.0548964E-006$$

$$\mu_u = 1.2912E+009$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01211878$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03444474$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.03444474$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00

Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c =$  confinement factor = 1.02437

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.07748884

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.04446081

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.07131877

and confined core properties:

b = 390.00

d = 877.00

d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0924687

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.05305581

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.08510586

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.19984886

Mu = MRc (4.14) = 1.2912E+009

u = su (4.1) = 7.0548964E-006

-----  
Calculation of ratio lb/d  
-----

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_2$ -

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 6.7307746E-006$$

$$\mu_u = 8.6158E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_u: \mu_u = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01211878$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01211878$$

$$\mu_{cc} \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03444474$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.03444474$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (\geq a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$

and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with

$Shear\_factor = 1.00$

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su_1 = 0.4 * esu_{1,nominal}$  ((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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

with  $Es_1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$

and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with

$Shear\_factor = 1.00$

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$

$su_2 = 0.4 * esu_{2,nominal}$  ((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  $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 389.0139$   
 with  $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$   
 $y_v = 0.00140044$   
 $sh_v = 0.0044814$   
 $ft_v = 466.8167$   
 $fy_v = 389.0139$   
 $su_v = 0.00512$   
 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  
 $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 $su_v = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$   
 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  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 389.0139$   
 with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.044446081$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.07748884$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07131877$

and confined core properties:

$b = 390.00$   
 $d = 877.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 33.80412$   
 $cc (5A.5, TBDY) = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.05305581$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0924687$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08510586$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16131742$   
 $Mu = MRc (4.14) = 8.6158E+008$   
 $u = su (4.1) = 6.7307746E-006$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.5528E+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.5528E+006$   
 $V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{ColO}$   
 $V_{ColO} = 1.5528E+006$   
 $knl = 1$  (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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $Mu = 57.90343$   
 $Vu = 0.00030591$   
 $d = 0.8 \cdot h = 760.00$   
 $Nu = 20792.019$

$A_g = 427500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$   
where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 977392.20$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$s/d = 0.13157895$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$

$s/d = 1.25$

$V_{s,c2} = 134042.359$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$

$s/d = 0.41666667$

$V_f$  ((11-3)-(11.4), ACI 440) = 477918.239

$f = 0.95$ , 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  $V_f(\alpha, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\alpha = 45^\circ$  and  $\alpha = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\alpha = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$ , with:

total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 907.00

$f_{fe}$  ((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:  $V_s + V_f \leq 1.3051E+006$

$b_w = 450.00$

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 1.5528E+006$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$

$V_{Col0} = 1.5528E+006$

$k_{nl} = 1$  (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).

-----  
 $\lambda = 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
MPa ((22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 57.90455$

$\nu_u = 0.00030591$

$d = 0.8 * h = 760.00$

$N_u = 20792.019$   
 $A_g = 427500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 977392.20$   
 $V_{s,j1} = 314161.779$  is calculated for section web jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:  
 $d = 760.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.13157895$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 477918.239  
 $f = 0.95$ , 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,  $t_{f1} = NL * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 907.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 1.3051E+006$   
 $b_w = 450.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
 At local axis: 2  
 -----

Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjtcs

Constant Properties

-----  
 Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 450.00$   
Max Width,  $W_{max} = 950.00$   
Min Width,  $W_{min} = 450.00$   
Eccentricity,  $E_{cc} = 200.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Secondary 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  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
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

Bending Moment,  $M = -197954.378$   
Shear Force,  $V_2 = 9672.998$   
Shear Force,  $V_3 = -199.8573$   
Axial Force,  $F = -22758.377$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 2475.575$   
-Compression:  $As_{l,com} = 1539.38$   
-Middle:  $As_{l,mid} = 2676.637$   
Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten,jacket} = 1859.823$   
-Compression:  $As_{l,com,jacket} = 1231.504$   
-Middle:  $As_{l,mid,jacket} = 2060.885$   
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten,core} = 615.7522$   
-Compression:  $As_{l,com,core} = 307.8761$   
-Middle:  $As_{l,mid,core} = 615.7522$   
Mean Diameter of Tension Reinforcement,  $Db_L = 16.72727$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.04320632$

$$u = y + p = 0.04320632$$

- Calculation of  $y$  -

$$y = (M_y * L_s / 3) / E_{\text{eff}} = 0.00120632 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 6.7046E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 990.4786$$

$$\text{From table 10.5, ASCE 41-17: } E_{\text{eff}} = \text{factor} * E_c * I_g = 1.8350E+014$$

$$\text{factor} = 0.30$$

$$A_g = 562500.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$$

$$N = 22758.377$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 6.1166E+014$$

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:

$$\text{flange width, } b = 950.00$$

$$\text{web width, } b_w = 450.00$$

$$\text{flange thickness, } t = 450.00$$

$$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$$

$$y_{\text{ten}} = 2.8728328E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$$

$$d = 707.00$$

$$y = 0.23388249$$

$$A = 0.01007179$$

$$B = 0.00604786$$

$$\text{with } p_t = 0.00368581$$

$$p_c = 0.00229194$$

$$p_v = 0.00398517$$

$$N = 22758.377$$

$$b = 950.00$$

$$" = 0.06082037$$

$$y_{\text{comp}} = 1.3500043E-005$$

$$\text{with } f_c' \text{ (12.3, (ACI 440))} = 33.25688$$

$$f_c = 33.00$$

$$f_l = 0.43533893$$

$$b = b_{\text{max}} = 950.00$$

$$h = h_{\text{max}} = 750.00$$

$$A_g = 0.5625$$

$$g = p_t + p_c + p_v = 0.00996292$$

$$r_c = 40.00$$

$$A_e / A_c = 0.30198841$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$\text{effective strain from (12.5) and (12.12), } e_{\text{fe}} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 26999.444$$

$$y = 0.23229755$$

$$A = 0.0098865$$

$$B = 0.00593898$$

$$\text{with } E_s = 200000.00$$

CONFIRMATION:  $y = 0.23299926 < t/d$

Calculation of ratio  $I_b / I_d$

Inadequate Lap Length with  $I_b / I_d = 0.30$

- Calculation of  $p$  -

From table 10-8:  $p = 0.042$

with:

- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$

shear control ratio  $V_y E / V_{col} O E = 0.51791795$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00568407$

jacket:  $s_1 = A_{v1} * L_{stir1} / (s_1 * A_g) = 0.00301593$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2160.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} * L_{stir2} / (s_2 * A_g) = 0.00056047$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1568.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2 * t_f / b_w * (f_{fe} / f_s)$  is implemented to account for FRP contribution

where  $f = 2 * t_f / b_w$  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.

$N_{UD} = 22758.377$

$A_g = 562500.00$

$f_{cE} = (f_{c,jacket} * Area_{jacket} + f_{c,core} * Area_{core}) / section\_area = 33.00$

$f_{yIE} = (f_{y,ext\_Long\_Reinf} * Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} * Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 555.56$

$f_{yIE} = (f_{y,ext\_Trans\_Reinf} * s_1 + f_{y,int\_Trans\_Reinf} * s_2) / (s_1 + s_2) = 555.56$

$p_l = Area_{Tot\_Long\_Rein} / (b * d) = 0.00996292$

$b = 950.00$

$d = 707.00$

$f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 15

column C1, Floor 1

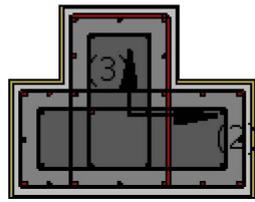
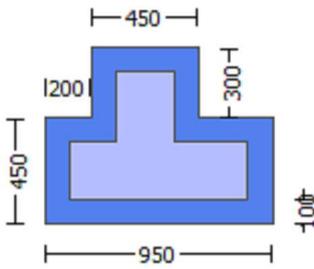
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JTC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Secondary 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

New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

New material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 26999.444$

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

New material: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material: Steel Strength,  $f_s = f_{sm} = 555.56$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $Ecc = 200.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary 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

Inadequate Lap Length with  $l_o/l_{o,min} = l_b/l_d = 0.30$

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,  $NoDir = 1$   
Fiber orientations,  $bi = 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties  
-----

EDGE -A-  
Bending Moment,  $M_a = -399933.566$   
Shear Force,  $V_a = 199.8573$   
EDGE -B-  
Bending Moment,  $M_b = -197954.378$   
Shear Force,  $V_b = -199.8573$   
BOTH EDGES  
Axial Force,  $F = -22758.377$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_{lt} = 0.00$   
-Compression:  $As_{lc} = 6691.592$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{l,ten} = 2475.575$   
-Compression:  $As_{l,com} = 1539.38$   
-Middle:  $As_{l,mid} = 2676.637$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.72727$

-----  
New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 1.2388E+006$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI} = 1.2388E+006$   
 $V_{CoI} = 1.2388E+006$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 1.0508140E-006$

-----  
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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)  
 $M / Vd = 2.00$   
 $M_u = 197954.378$   
 $V_u = 199.8573$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 22758.377$   
 $A_g = 337500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 842449.486$   
where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 753982.237$   
 $V_{s,j1} = 471238.898$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col_{j1} = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 282743.339$  is calculated for section flange jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col_{j2} = 1.00$   
 $s/d = 0.27777778$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 88467.249$   
 $V_{s,c1} = 88467.249$  is calculated for section web core, with:  
 $d = 440.00$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

$V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$

$$s/d = 0.56818182$$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

$V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$

$$s/d = 1.25$$

$$V_f((11-3)-(11.4), ACI 440) = 372533.843$$

$f = 0.95$ , 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:  $\theta = b1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|), \text{ with:}$$

total thickness per orientation,  $tf1 = NL * t / \text{NoDir} = 1.016$

$$dfv = d \text{ (figure 11.2, ACI 440)} = 707.00$$

$$ffe((11-5), ACI 440) = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

with  $f_u = 0.01$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 896810.169$$

$$bw = 450.00$$

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  $\theta = 1.2676135E-009$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00120632 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 6.7046E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 990.4786$$

$$\text{From table 10.5, ASCE 41-17: } E_{eff} = \text{factor} * E_c * I_g = 1.8350E+014$$

$$\text{factor} = 0.30$$

$$A_g = 562500.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$$

$$N = 22758.377$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 6.1166E+014$$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $\delta / y < t/d$ , compression zone rectangular) with:

$$\text{flange width, } b = 950.00$$

$$\text{web width, } bw = 450.00$$

$$\text{flange thickness, } t = 450.00$$

$$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$$

$$y_{\text{ten}} = 2.8728328E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$$

$$d = 707.00$$

$$y = 0.23388249$$

$$A = 0.01007179$$

$$B = 0.00604786$$

$$\text{with } pt = 0.00368581$$

pc = 0.00229194  
pv = 0.00398517  
N = 22758.377  
b = 950.00  
" = 0.06082037  
y\_comp = 1.3500043E-005  
with fc\* (12.3, (ACI 440)) = 33.25688  
fc = 33.00  
fl = 0.43533893  
b = bmax = 950.00  
h = hmax = 750.00  
Ag = 0.5625  
g = pt + pc + pv = 0.00996292  
rc = 40.00  
Ae/Ac = 0.30198841  
Effective FRP thickness, tf = NL\*t\*Cos(b1) = 1.016  
effective strain from (12.5) and (12.12), efe = 0.004  
fu = 0.01  
Ef = 64828.00  
Ec = 26999.444  
y = 0.23229755  
A = 0.0098865  
B = 0.00593898  
with Es = 200000.00  
CONFIRMATION: y = 0.23299926 < t/d

-----  
-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Inadequate Lap Length with lb/l<sub>d</sub> = 0.30  
-----

End Of Calculation of Shear Capacity for element: column JTC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
-----

## Calculation No. 16

column C1, Floor 1

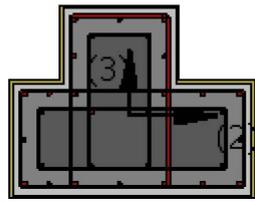
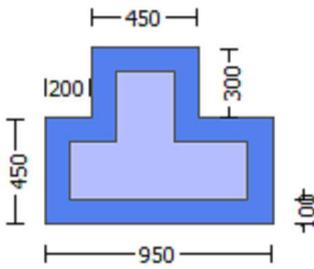
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( u)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1

At Shear local axis: 3  
 (Bending local axis: 2)  
 Section Type: rcjtcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

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

New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $E_{cc} = 200.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.02437

Element Length,  $L = 3000.00$

Secondary 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

Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$

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

At local axis: 3  
EDGE -A-  
Shear Force, Va = -4.9265533E-005  
EDGE -B-  
Shear Force, Vb = 4.9265533E-005  
BOTH EDGES  
Axial Force, F = -20792.019  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 6691.592  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 2475.575  
-Compression: Asl,com = 1539.38  
-Middle: Asl,mid = 2676.637

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.51791795$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 635124.647$   
with  
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 9.5269E+008$   
 $\mu_{1+} = 9.5269E+008$ , 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  
 $\mu_{1-} = 6.8428E+008$ , 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  
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 9.5269E+008$   
 $\mu_{2+} = 9.5269E+008$ , 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  
 $\mu_{2-} = 6.8428E+008$ , 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:  
 $\mu = 8.7398457E-006$   
 $\mu_u = 9.5269E+008$

with full section properties:

$$b = 950.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093808$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, c_c) = 0.01211878$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.01211878$$

$$\mu_u \text{ ((5.4c), TBDY)} = a_s e^* \text{ sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

where  $f = a_f * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03444474$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 160566.667$$

$$b_{\text{max}} = 950.00$$

hmax = 750.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

fy = 0.03444474  
Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
af = 0.28545185  
with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$   
bmax = 950.00  
hmax = 750.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

R = 40.00  
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015

ase ((5.4d), TBDY) =  $(ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.53070105$

ase1 =  $Max(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

ase2 ( $\geq ase1$ ) =  $Max(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min}*F_{ywe} = Min(psh_x*F_{ywe}, psh_y*F_{ywe}) = 2.48363$

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)

$psh_x*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.48363$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00301593$   
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00056047$   
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

$psh_y*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 2.97078$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1}*A_{stir1}/(A_{sec}*s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $L_{stir2}*A_{stir2}/(A_{sec}*s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00  
s1 = 100.00

$s_2 = 250.00$   
 $fy_{we1} = 694.45$   
 $fy_{we2} = 694.45$   
 $f_{ce} = 33.00$   
 From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $y_1 = 0.00140044$   
 $sh_1 = 0.0044814$   
 $ft_1 = 466.8167$   
 $fy_1 = 389.0139$   
 $su_1 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/d = 0.30$   
 $su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esu_1 \text{ nominal} = 0.08$ ,  
 For calculation of  $esu_1 \text{ nominal}$  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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$   
 with  $Es_1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$   
 $y_2 = 0.00140044$   
 $sh_2 = 0.0044814$   
 $ft_2 = 466.8167$   
 $fy_2 = 389.0139$   
 $su_2 = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/lb, \min = 0.30$   
 $su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esu_2 \text{ nominal} = 0.08$ ,  
 For calculation of  $esu_2 \text{ nominal}$  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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 389.0139$   
 with  $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$   
 $y_v = 0.00140044$   
 $sh_v = 0.0044814$   
 $ft_v = 466.8167$   
 $fy_v = 389.0139$   
 $suv = 0.00512$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/d = 0.30$   
 $suv = 0.4 * esuv \text{ nominal ((5.5), TBDY)} = 0.032$   
 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  $y_v, sh_v, ft_v, fy_v$ , 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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 389.0139$   
 with  $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / f_c) = 0.04344945$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / f_c) = 0.02701806$   
 $v = A_{sl,mid} / (b * d) * (fsv / f_c) = 0.04697834$   
 and confined core properties:  
 $b = 890.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} \text{ (5A.2, TBDY)} = 33.80412$   
 $cc \text{ (5A.5, TBDY)} = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $1 = A_{sl,ten} / (b * d) * (fs_1 / f_c) = 0.04843381$   
 $2 = A_{sl,com} / (b * d) * (fs_2 / f_c) = 0.03011747$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05236752$$

Case/Assumption: Unconfined full section - Steel rupture  
satisfies Eq. (4.3)

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$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

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$$s_u(4.9) = 0.17139647$$

$$M_u = M_{Rc}(4.14) = 9.5269E+008$$

$$u = s_u(4.1) = 8.7398457E-006$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $M_{u1}$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 8.8144127E-006$$

$$M_u = 6.8428E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$\alpha(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear\_factor} \cdot \text{Max}(\alpha, \alpha_c) = 0.01211878$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \alpha_c = 0.01211878$$

$$\alpha_{we} \text{ ((5.4c), TB DY) } = \alpha_{se} \cdot \text{sh}_{, \min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

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)

$$f_x = 0.03444474$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cdot \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TB DY) } = (\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.53070105$$

$$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) \cdot (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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)

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$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

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 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

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 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 562500.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1_{nominal}$  ((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  $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

with  $Es1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.00140044$

$sh_2 = 0.0044814$   
 $ft_2 = 466.8167$   
 $fy_2 = 389.0139$   
 $su_2 = 0.00512$   
 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  
 $lo/lo_{min} = lb/lb_{min} = 0.30$   
 $su_2 = 0.4 * esu_{2\_nominal} ((5.5), TBDY) = 0.032$   
 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  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 389.0139$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.00140044$   
 $shv = 0.0044814$   
 $ftv = 466.8167$   
 $fyv = 389.0139$   
 $suv = 0.00512$   
 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  
 $lo/lo_{min} = lb/ld = 0.30$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 389.0139$   
 with  $Esv = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.05703813$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.09172662$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.0991765$   
 and confined core properties:  
 $b = 390.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 33.80412$   
 $cc (5A.5, TBDY) = 0.00224367$   
 $c = \text{confinement factor} = 1.02437$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.06872961$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.11052844$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.11950537$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.17840617$   
 $Mu = MRc (4.14) = 6.8428E+008$   
 $u = su (4.1) = 8.8144127E-006$

-----  
 Calculation of ratio  $lb/ld$   
 -----

Inadequate Lap Length with  $lb/ld = 0.30$   
 -----  
 -----

-----  
 Calculation of  $Mu_{2+}$   
 -----

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 8.7398457E-006$

Mu = 9.5269E+008

with full section properties:

b = 950.00

d = 707.00

d' = 43.00

v = 0.00093808

N = 20792.019

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01211878

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01211878

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+ Min( fx, fy) = 0.04642716

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.03444474

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.28545185

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 160566.667

bmax = 950.00

hmax = 750.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

fy = 0.03444474

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.28545185

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 160566.667

bmax = 950.00

hmax = 750.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

R = 40.00

Effective FRP thickness, tf = NL\*t\*Cos(b1) = 1.016

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.53070105

ase1 = Max(((Aconf,max1-AnoConf1)/Aconf,max1)\*(Aconf,min1/Aconf,max1),0) = 0.53070105

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 = 464100.00 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 = 395025.00 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 = 174733.333 is the unconfined external core area which is equal to bi2/6 as defined at (A.2).

ase2 (>=ase1) = Max(((Aconf,max2-AnoConf2)/Aconf,max2)\*(Aconf,min2/Aconf,max2),0) = 0.53070105

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 = 252164.00 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 = 111441.00 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 = 112376.00 is the unconfined internal core area which is equal to bi2/6 as defined at (A.2).

psh,min\*Fywe = Min(psh,x\*Fywe, psh,y\*Fywe) = 2.48363

Expression (5.4d) for  $psh_{min} \cdot Fy_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot Fy_{we} = psh1 \cdot Fy_{we1} + ps2 \cdot Fy_{we2} = 2.48363$   
 $psh1$  ((5.4d), TBDY) =  $Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.00301593$   
Lstir1 (Length of stirrups along Y) = 2160.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00056047$   
Lstir2 (Length of stirrups along Y) = 1568.00  
Astir2 (stirrups area) = 50.26548

$psh_y \cdot Fy_{we} = psh1 \cdot Fy_{we1} + ps2 \cdot Fy_{we2} = 2.97078$   
 $psh1$  ((5.4d), TBDY) =  $Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00  
s1 = 100.00  
s2 = 250.00  
fywe1 = 694.45  
fywe2 = 694.45  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367  
c = confinement factor = 1.02437

y1 = 0.00140044  
sh1 = 0.0044814  
ft1 = 466.8167  
fy1 = 389.0139  
su1 = 0.00512

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 = 0.30

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 =  $(fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 389.0139$

with Es1 =  $(Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$

y2 = 0.00140044  
sh2 = 0.0044814  
ft2 = 466.8167  
fy2 = 389.0139  
su2 = 0.00512

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 = 0.30

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 =  $(fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 389.0139$

with Es2 =  $(Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

yv = 0.00140044  
shv = 0.0044814  
ftv = 466.8167  
fyv = 389.0139  
suv = 0.00512

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

$$l_0/l_{ou,min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{suv,nominal} = 0.08$ ,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv,nominal}$  and  $\gamma_v$ ,  $sh_v, ft_v, fy_v$ , it is considered

characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$$\gamma_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from } 10.3.5, \text{ ASCE } 41-17.$$

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 389.0139$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.04344945$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.02701806$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.04697834$$

and confined core properties:

$$b = 890.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.80412$$

$$c_c (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.04843381$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.03011747$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.05236752$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.17139647$$

$$M_u = M_{Rc} (4.14) = 9.5269E+008$$

$$u = s_u (4.1) = 8.7398457E-006$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_2$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 8.8144127E-006$$

$$M_u = 6.8428E+008$$

with full section properties:

$$b = 450.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00198039$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, c_c) = 0.01211878$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.01211878$$

$$\text{we ((5.4c), TBDY) } = a_{se} * sh_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03444474$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

fy = 0.03444474  
Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$   
af = 0.28545185  
with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 160566.667$   
bmax = 950.00  
hmax = 750.00  
From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00  
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015

ase ((5.4d), TBDY) =  $(ase_1 * A_{ext} + ase_2 * A_{int})/A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$$fy_{we2} = 694.45$$

$$f_{ce} = 33.00$$

From ((5.A.5), TBDY), TBDY:  $cc = 0.00224367$

$$c = \text{confinement factor} = 1.02437$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

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

$$lo/lou, \min = lb/ld = 0.30$$

$$su_1 = 0.4 * esu_{1, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY:  $esu_{1, \text{nominal}} = 0.08$ ,

For calculation of  $esu_{1, \text{nominal}}$  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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = (fs_{\text{jacket}} * Asl, \text{ten, jacket} + fs_{\text{core}} * Asl, \text{ten, core}) / Asl, \text{ten} = 389.0139$$

$$\text{with } Es_1 = (Es_{\text{jacket}} * Asl, \text{ten, jacket} + Es_{\text{core}} * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

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

$$lo/lou, \min = lb/lb, \min = 0.30$$

$$su_2 = 0.4 * esu_{2, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY:  $esu_{2, \text{nominal}} = 0.08$ ,

For calculation of  $esu_{2, \text{nominal}}$  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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_{\text{jacket}} * Asl, \text{com, jacket} + fs_{\text{core}} * Asl, \text{com, core}) / Asl, \text{com} = 389.0139$$

$$\text{with } Es_2 = (Es_{\text{jacket}} * Asl, \text{com, jacket} + Es_{\text{core}} * Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$suv = 0.00512$$

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

$$lo/lou, \min = lb/ld = 0.30$$

$$suv = 0.4 * esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

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  $y_v, sh_v, ft_v, fy_v$ , 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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs_{\text{jacket}} * Asl, \text{mid, jacket} + fs_{\text{mid}} * Asl, \text{mid, core}) / Asl, \text{mid} = 389.0139$$

$$\text{with } Es_v = (Es_{\text{jacket}} * Asl, \text{mid, jacket} + Es_{\text{mid}} * Asl, \text{mid, core}) / Asl, \text{mid} = 200000.00$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / f_c) = 0.05703813$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / f_c) = 0.09172662$$

$$v = Asl, \text{mid} / (b * d) * (fsv / f_c) = 0.0991765$$

and confined core properties:

$$b = 390.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, \text{TBDY}) = 33.80412$$

$$cc (5A.5, \text{TBDY}) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / f_c) = 0.06872961$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / f_c) = 0.11052844$$

$$v = Asl, \text{mid} / (b * d) * (fsv / f_c) = 0.11950537$$

Case/Assumption: Unconfinedsd full section - Steel rupture

satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$\mu_u (4.9) = 0.17840617$$

$$\mu_u = M/R_c (4.14) = 6.8428E+008$$

$$u = \mu_u (4.1) = 8.8144127E-006$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----  
-----

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.2263E+006$   
-----

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 1.2263E+006$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{ColO}$$

$$V_{ColO} = 1.2263E+006$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

-----  
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 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_c \text{ jacket} * \text{Area}_{\text{jacket}} + f'_c \text{ core} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)

$$M/d = 4.00$$

$$\mu_u = 7.32046$$

$$V_u = 4.9265533E-005$$

$$d = 0.8 * h = 600.00$$

$$N_u = 20792.019$$

$$A_g = 337500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 936062.473$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$$

$V_{s,j1} = 523602.964$  is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$$s/d = 0.16666667$$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.27777778$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$

$$s/d = 0.56818182$$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$

$$s/d = 1.25$$

$$V_f((11-3)-(11.4), \text{ACI 440}) = 372533.843$$

$f = 0.95$ , 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:  $\theta = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$ , 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:  $V_s + V_f \leq 1.0304E+006$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 1.2263E+006$

$V_{r2} = V_{Col}((10.3), \text{ASCE 41-17}) = k_{nl} * V_{Col0}$

$V_{Col0} = 1.2263E+006$

$k_{nl} = 1$  (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).

$\lambda = 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/d = 4.00$

$\mu_u = 7.3142$

$V_u = 4.9265533E-005$

$d = 0.8 * h = 600.00$

$N_u = 20792.019$

$A_g = 337500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 936062.473$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 837764.743$

$V_{s,j1} = 523602.964$  is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $Col_{j1} = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 314161.779$  is calculated for section flange jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $Col_{j2} = 1.00$

$s/d = 0.27777778$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$  is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col_{c1} = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$  is calculated for section flange core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col_{c2} = 0.00$

s/d = 1.25

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 + cota) sina which is more a generalised expression, where 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° and = -45° to take into consideration the cyclic seismic loading.

orientation 1: 1 = b1 + 90° = 90.00

Vf = Min(|Vf(45, 1)|, |Vf(-45,a1)|), with:

total thickness per orientation, tf1 = NL\*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 <= 1.0304E+006

bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjtcs

Constant Properties

Knowledge Factor, = 1.00

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, fc = fcm = 33.00

New material of Secondary Member: Steel Strength, fs = fsm = 555.56

Concrete Elasticity, Ec = 26999.444

Steel Elasticity, Es = 200000.00

Existing Column

New material of Secondary Member: Concrete Strength, fc = fcm = 33.00

New material of Secondary Member: Steel Strength, fs = fsm = 555.56

Concrete Elasticity, Ec = 26999.444

Steel Elasticity, Es = 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, fs = 1.25\*fsm = 694.45

Existing Column

New material: Steel Strength, fs = 1.25\*fsm = 694.45

#####  
Max Height, Hmax = 750.00

Min Height, Hmin = 450.00

Max Width, Wmax = 950.00

Min Width, Wmin = 450.00

Eccentricity, Ecc = 200.00

Jacket Thickness, tj = 100.00

Cover Thickness, c = 25.00

Mean Confinement Factor overall section = 1.02437

Element Length, L = 3000.00

Secondary 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

Inadequate Lap Length with  $l_o/l_{ou,min} = 0.30$

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

-----  
At local axis: 2

EDGE -A-

Shear Force,  $V_a = 0.00030591$

EDGE -B-

Shear Force,  $V_b = -0.00030591$

BOTH EDGES

Axial Force,  $F = -20792.019$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 6691.592$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 2682.92$

-Compression:  $As_{c,com} = 1539.38$

-Middle:  $As_{mid} = 2469.292$

-----  
-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.55437584$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 860817.439$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.2912E+009$

$Mu_{1+} = 1.2912E+009$ , 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

$Mu_{1-} = 8.6158E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.2912E+009$

$Mu_{2+} = 1.2912E+009$ , 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

$Mu_{2-} = 8.6158E+008$ , 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  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 7.0548964E-006$

$M_u = 1.2912E+009$

-----  
with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.019$

$f_c = 33.00$

$\alpha (\text{5A.5, TBDY}) = 0.002$

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.01211878$

$w_e$  ((5.4c), TBDY) =  $a_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.03444474$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $f_y = 0.03444474$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.28545185$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 160566.667$

$b_{\max} = 950.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $R = 40.00$

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), TBDY) =  $(a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.53070105$

$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.53070105$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.53070105$

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.

$A_{\text{conf,max2}} = 252164.00$  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.

$A_{\text{conf,min2}} = 111441.00$  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.

$A_{\text{noConf2}} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  ((5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.97078$   
 $psh1 ((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00357443$   
 Lstir1 (Length of stirrups along X) = 2560.00  
 Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2 * Astir2 / (Asec * s2) = 0.00070345$   
 Lstir2 (Length of stirrups along X) = 1968.00  
 Astir2 (stirrups area) = 50.26548

Asec = 562500.00  
 s1 = 100.00  
 s2 = 250.00

fywe1 = 694.45  
 fywe2 = 694.45  
 fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367  
 c = confinement factor = 1.02437

y1 = 0.00140044  
 sh1 = 0.0044814  
 ft1 = 466.8167  
 fy1 = 389.0139  
 su1 = 0.00512

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

$lo/lou, min = lb/ld = 0.30$

$su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$

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 =  $(fs\_jacket * Asl, ten, jacket + fs\_core * Asl, ten, core) / Asl, ten = 389.0139$

with Es1 =  $(Es\_jacket * Asl, ten, jacket + Es\_core * Asl, ten, core) / Asl, ten = 200000.00$

y2 = 0.00140044  
 sh2 = 0.0044814  
 ft2 = 466.8167  
 fy2 = 389.0139  
 su2 = 0.00512

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

$lo/lou, min = lb/lb, min = 0.30$

$su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$

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 =  $(fs\_jacket * Asl, com, jacket + fs\_core * Asl, com, core) / Asl, com = 389.0139$

with Es2 =  $(Es\_jacket * Asl, com, jacket + Es\_core * Asl, com, core) / Asl, com = 200000.00$

yv = 0.00140044  
 shv = 0.0044814  
 ftv = 466.8167  
 fyv = 389.0139  
 suv = 0.00512

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

$lo/lou, min = lb/ld = 0.30$

$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$

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 =  $(fs\_jacket * Asl, mid, jacket + fs\_mid * Asl, mid, core) / Asl, mid = 389.0139$

with Esv =  $(Es\_jacket * Asl, mid, jacket + Es\_mid * Asl, mid, core) / Asl, mid = 200000.00$

$1 = Asl, ten / (b * d) * (fs1 / fc) = 0.07748884$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.04446081$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07131877$$

and confined core properties:

$$b = 390.00$$

$$d = 877.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 33.80412$$

$$c_c (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0924687$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.05305581$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08510586$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.19984886$$

$$\mu_u = M_{Rc} (4.14) = 1.2912E+009$$

$$u = s_u (4.1) = 7.0548964E-006$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 6.7307746E-006$$

$$\mu_u = 8.6158E+008$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01211878$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01211878$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03444474$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 160566.667$$

$$b_{max} = 950.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00  
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c =$  confinement factor = 1.02437

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 389.0139

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 389.0139

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 389.0139

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04446081

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.07748884

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.07131877

and confined core properties:

b = 390.00

d = 877.00

d' = 13.00

fcc (5A.2, TBDY) = 33.80412

cc (5A.5, TBDY) = 0.00224367

c = confinement factor = 1.02437

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.05305581

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0924687

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.08510586

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16131742

Mu = MRc (4.14) = 8.6158E+008

u = su (4.1) = 6.7307746E-006

-----  
Calculation of ratio lb/ld

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 7.0548964E-006$$

$$\mu_u = 1.2912E+009$$

with full section properties:

$$b = 450.00$$

$$d = 907.00$$

$$d' = 43.00$$

$$v = 0.0015437$$

$$N = 20792.019$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.01211878$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.01211878$$

$$\mu_{ve} \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{,\min} * f_{yve}/f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$$

where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03444474$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.03444474$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.28545185$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 160566.667$$

$$b_{\max} = 950.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.53070105$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.53070105$$

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.

$A_{\text{conf,max1}} = 464100.00$  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.

$A_{\text{conf,min1}} = 395025.00$  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.

$A_{\text{noConf1}} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (> a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.53070105$$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.97078$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00357443$

$L_{stir1}$  (Length of stirrups along X) = 2560.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00070345$

$L_{stir2}$  (Length of stirrups along X) = 1968.00

$A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 562500.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00224367$

$c = \text{confinement factor} = 1.02437$

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$

and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with

$Shear\_factor = 1.00$

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su_1 = 0.4 * esu1\_nominal$  ((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  $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

with  $Es_1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$

and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with

$Shear\_factor = 1.00$

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$

$su_2 = 0.4 * esu2\_nominal$  ((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  $fs_2 = (fs_{jacket} \cdot A_{s1,com,jacket} + fs_{core} \cdot A_{s1,com,core}) / A_{s1,com} = 389.0139$

with  $Es_2 = (Es_{jacket} \cdot A_{s1,com,jacket} + Es_{core} \cdot A_{s1,com,core}) / A_{s1,com} = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$suv = 0.00512$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

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  $fsv = (fs_{jacket} \cdot A_{s,mid,jacket} + fs_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 389.0139$

with  $Es_v = (Es_{jacket} \cdot A_{s,mid,jacket} + Es_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.07748884$

$2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04446081$

$v = A_{s,mid} / (b \cdot d) \cdot (fsv / fc) = 0.07131877$

and confined core properties:

$b = 390.00$

$d = 877.00$

$d' = 13.00$

$fcc$  (5A.2, TBDY) = 33.80412

$cc$  (5A.5, TBDY) = 0.00224367

$c$  = confinement factor = 1.02437

$1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0924687$

$2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05305581$

$v = A_{s,mid} / (b \cdot d) \cdot (fsv / fc) = 0.08510586$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su$  (4.9) = 0.19984886

$Mu = MRc$  (4.14) = 1.2912E+009

$u = su$  (4.1) = 7.0548964E-006

-----  
Calculation of ratio  $l_b/l_d$

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Inadequate Lap Length with  $l_b/l_d = 0.30$   
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Calculation of  $Mu_2$ -  
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-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 6.7307746E-006$

$Mu = 8.6158E+008$   
-----

with full section properties:

$b = 450.00$

$d = 907.00$

$d' = 43.00$

$v = 0.0015437$

$N = 20792.019$

$fc = 33.00$

$co$  (5A.5, TBDY) = 0.002

Final value of  $cu$ :  $cu^* = \text{shear\_factor} \cdot \text{Max}(cu, cc) = 0.01211878$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.01211878$

$w_e$  ((5.4c), TBDY) =  $ase * sh_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.04642716$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.03444474$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.28545185$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.03444474$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.28545185$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 160566.667$

$b_{max} = 950.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$

Effective FRP thickness,  $t_f = NL * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,e} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.53070105$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.53070105$

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.

$A_{conf,max1} = 464100.00$  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.

$A_{conf,min1} = 395025.00$  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.

$A_{noConf1} = 174733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase_2 (\geq ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.53070105$

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.

$A_{conf,max2} = 252164.00$  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.

$A_{conf,min2} = 111441.00$  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.

$A_{noConf2} = 112376.00$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.48363$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.48363$

$p_{sh1}$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00301593$

$L_{stir1}$  (Length of stirrups along Y) = 2160.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2}$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00056047$

$L_{stir2}$  (Length of stirrups along Y) = 1568.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.97078$

psh1 ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00357443$   
Lstir1 (Length of stirrups along X) = 2560.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00070345$   
Lstir2 (Length of stirrups along X) = 1968.00  
Astir2 (stirrups area) = 50.26548

Asec = 562500.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00224367

c = confinement factor = 1.02437

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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 = 0.30

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 =  $(fs\_jacket * A_{sl,ten,jacket} + fs\_core * A_{sl,ten,core}) / A_{sl,ten} = 389.0139$

with Es1 =  $(Es\_jacket * A_{sl,ten,jacket} + Es\_core * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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 = 0.30

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 =  $(fs\_jacket * A_{sl,com,jacket} + fs\_core * A_{sl,com,core}) / A_{sl,com} = 389.0139$

with Es2 =  $(Es\_jacket * A_{sl,com,jacket} + Es\_core * A_{sl,com,core}) / A_{sl,com} = 200000.00$

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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 = 0.30

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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv =  $(fs\_jacket * A_{sl,mid,jacket} + fs\_mid * A_{sl,mid,core}) / A_{sl,mid} = 389.0139$

with Esv =  $(Es\_jacket * A_{sl,mid,jacket} + Es\_mid * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$

1 =  $A_{sl,ten} / (b * d) * (fs1 / fc) = 0.04446081$

2 =  $A_{sl,com} / (b * d) * (fs2 / fc) = 0.07748884$

v =  $A_{sl,mid} / (b * d) * (fsv / fc) = 0.07131877$

and confined core properties:

$$b = 390.00$$

$$d = 877.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 33.80412$$

$$cc (5A.5, TBDY) = 0.00224367$$

$$c = \text{confinement factor} = 1.02437$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05305581$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.0924687$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08510586$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

---

$$s_u (4.9) = 0.16131742$$

$$\mu = MR_c (4.14) = 8.6158E+008$$

$$u = s_u (4.1) = 6.7307746E-006$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.5528E+006$

Calculation of Shear Strength at edge 1,  $V_{r1} = 1.5528E+006$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 1.5528E+006$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 57.90343$$

$$V_u = 0.00030591$$

$$d = 0.8 * h = 760.00$$

$$N_u = 20792.019$$

$$A_g = 427500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$$

where:

$$V_{s,jacket} = V_{sj1} + V_{sj2} = 977392.20$$

$V_{sj1} = 314161.779$  is calculated for section web jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{sj1}$  is multiplied by  $Col_{j1} = 1.00$

$$s/d = 0.27777778$$

$V_{sj2} = 663230.422$  is calculated for section flange jacket, with:

$$d = 760.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{sj2}$  is multiplied by  $Col_{j2} = 1.00$

$$s/d = 0.13157895$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$f_y = 555.56$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.25$   
 $V_{s,c2} = 134042.359$  is calculated for section flange core, with:  
 $d = 600.00$   
 $A_v = 100530.965$   
 $f_y = 555.56$   
 $s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.41666667$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 477918.239

$f = 0.95$ , 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:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , with:

total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 907.00

$f_{fe}$  ((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:  $V_s + V_f \leq 1.3051E+006$

$bw = 450.00$

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 1.5528E+006$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$

$V_{Col0} = 1.5528E+006$

$k_{nl} = 1$  (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).

-----  
 $\rho = 1$  (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/d = 4.00$

$\mu_u = 57.90455$

$V_u = 0.00030591$

$d = 0.8 * h = 760.00$

$N_u = 20792.019$

$A_g = 427500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 1.1114E+006$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 977392.20$

$V_{s,j1} = 314161.779$  is calculated for section web jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$s/d = 0.27777778$

$V_{s,j2} = 663230.422$  is calculated for section flange jacket, with:

$d = 760.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$s/d = 0.13157895$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 134042.359$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$

$s/d = 1.25$

$V_{s,c2} = 134042.359$  is calculated for section flange core, with:

$d = 600.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$

$s/d = 0.41666667$

$V_f$  ((11-3)-(11.4), ACI 440) = 477918.239

$f = 0.95$ , 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:  $\theta = 45^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a)|)$ , with:

total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 907.00

$f_{fe}$  ((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:  $V_s + V_f \leq 1.3051E+006$

$b_w = 450.00$

-----  
-----  
End Of Calculation of Shear Capacity ratio for element: column JTC1 of floor 1  
At local axis: 2

-----  
-----  
Start Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
Section Type: rcjtcs

Constant Properties

-----  
Knowledge Factor,  $\gamma = 1.00$

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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 450.00$

Max Width,  $W_{max} = 950.00$

Min Width,  $W_{min} = 450.00$

Eccentricity,  $E_{cc} = 200.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary 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  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
 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

-----  
 Bending Moment,  $M = 440405.491$   
 Shear Force,  $V_2 = 9672.998$   
 Shear Force,  $V_3 = -199.8573$   
 Axial Force,  $F = -22758.377$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $As_{lt} = 0.00$   
 -Compression:  $As_{lc} = 6691.592$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten} = 2682.92$   
 -Compression:  $As_{l,com} = 1539.38$   
 -Middle:  $As_{l,mid} = 2469.292$   
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten,jacket} = 2375.044$   
 -Compression:  $As_{l,com,jacket} = 1231.504$   
 -Middle:  $As_{l,mid,jacket} = 1545.664$   
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten,core} = 307.8761$   
 -Compression:  $As_{l,com,core} = 307.8761$   
 -Middle:  $As_{l,mid,core} = 923.6282$   
 Mean Diameter of Tension Reinforcement,  $DbL = 17.45455$

-----  
 New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.04231158$   
 $u = y + p = 0.04231158$

-----  
 - Calculation of  $y$  -

-----  
 $y = (M_y * L_s / 3) / E_{eff} = 0.00031158$  ((4.29), Biskinis Phd))  
 $M_y = 8.7538E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $300.00$   
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.8095E+014$   
 $factor = 0.30$   
 $A_g = 562500.00$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 22758.377$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.3651E+014$

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 Calculation of Yielding Moment  $M_y$

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 Calculation of  $y$  and  $M_y$  according to Annex 7 -

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 $y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 2.3929630E-006$   
 with  $((10.1), ASCE 41-17) f_y = \text{Min}(f_y, 1.25*f_y*(l_b/l_d)^{2/3}) = 311.2112$   
 $d = 907.00$   
 $y = 0.28306153$   
 $A = 0.0165741$   
 $B = 0.01009974$   
 with  $pt = 0.00657337$   
 $pc = 0.0037716$   
 $pv = 0.00604996$   
 $N = 22758.377$   
 $b = 450.00$   
 $" = 0.04740904$

$y_{comp} = 8.6873791E-006$   
 with  $f_c^* (12.3, (ACI 440)) = 33.253$   
 $f_c = 33.00$   
 $f_l = 0.43533893$   
 $b = b_{max} = 950.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.5625$   
 $g = pt + pc + pv = 0.01639493$   
 $rc = 40.00$   
 $A_e/A_c = 0.29742395$   
 Effective FRP thickness,  $t_f = NL*t*\text{Cos}(b1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.28135356$   
 $A = 0.01626917$   
 $B = 0.00992057$   
 with  $E_s = 200000.00$

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 Calculation of ratio  $l_b/l_d$

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 Inadequate Lap Length with  $l_b/l_d = 0.30$

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 - Calculation of  $p$  -

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 From table 10-8:  $p = 0.042$

with:

- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$

shear control ratio  $V_yE/V_{CoIOE} = 0.55437584$

$d = d_{external} = 907.00$

$s = s_{external} = 0.00$

-  $t = s_1 + s_2 + 2*t_f/bw*(f_{fe}/f_s) = 0.00638555$

jacket:  $s_1 = A_{v1}*L_{stir1}/(s_1*A_g) = 0.00357443$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2560.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2}*L_{stir2}/(s_2*A_g) = 0.00070345$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1968.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2*t_f/bw*(f_{fe}/f_s)$  is implemented to account for FRP contribution

where  $f = 2*t_f/bw$  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.

$NUD = 22758.377$

$A_g = 562500.00$

$f_cE = (f_c*jacket*Area_{jacket} + f_c*core*Area_{core})/section\_area = 33.00$

$f_yE = (f_y_{ext\_Long\_Reinf}*Area_{ext\_Long\_Reinf} + f_y_{int\_Long\_Reinf}*Area_{int\_Long\_Reinf})/Area_{Tot\_Long\_Rein} = 555.56$

$f_yE = (f_y_{ext\_Trans\_Reinf}*s_1 + f_y_{int\_Trans\_Reinf}*s_2)/(s_1 + s_2) = 555.56$

$pl = Area_{Tot\_Long\_Rein}/(b*d) = 0.01639493$

b = 450.00  
d = 907.00  
f<sub>cE</sub> = 33.00

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End Of Calculation of Chord Rotation Capacity for element: column JTC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
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