

# Detailed Member Calculations

**Units: N&mm**

**Regulation: ASCE 41-17**

## Calculation No. 1

column C1, Floor 1

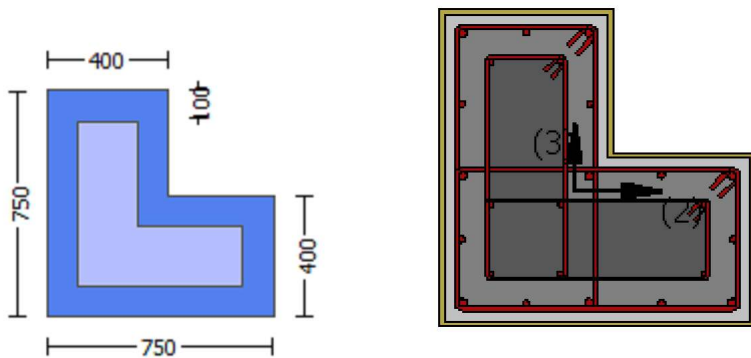
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rcjcs

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 Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$

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

Concrete Elasticity,  $E_c = 25742.96$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$   
Concrete Elasticity,  $E_c = 23025.204$   
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,  $f_c = f_{cm} = 30.00$   
New material: Steel Strength,  $f_s = f_{sm} = 625.00$   
Existing Column  
Existing material: Concrete Strength,  $f_c = f_{cm} = 24.00$   
Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Primary Member  
Smooth Bars  
Ductile Steel  
With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )  
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $bi: 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

EDGE -A-  
Bending Moment,  $M_a = -1.6212E+007$   
Shear Force,  $V_a = -5348.301$   
EDGE -B-  
Bending Moment,  $M_b = 163137.319$   
Shear Force,  $V_b = 5348.301$   
BOTH EDGES  
Axial Force,  $F = -17151.026$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 5353.274$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{l,ten} = 1137.257$   
-Compression:  $As_{l,com} = 2208.54$   
-Middle:  $As_{l,mid} = 2007.478$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = *V_n = 813477.17$

$V_n$  ((10.3), ASCE 41-17) =  $k_n I^* V_{ColO} = 813477.17$

$V_{Col} = 813477.17$

$k_n I = 1.00$

$\text{displacement\_ductility\_demand} = 0.01316221$

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

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot \text{Area}_{jacket} + f'_{c\_core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 18.36364$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 4.00$

$\mu_u = 1.6212E+007$

$V_u = 5348.301$

$d = 0.8 \cdot h = 600.00$

$N_u = 17151.026$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 796878.80$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 722566.31$

$V_{sj1} = 251327.412$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{sj1}$  is multiplied by  $Col_{j1} = 1.00$

$s/d = 0.3125$

$V_{sj2} = 471238.898$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{sj2}$  is multiplied by  $Col_{j2} = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 74312.489$

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

$d = 160.00$

$A_v = 100530.965$

$f_y = 420.00$

$s = 250.00$

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

$s/d = 1.5625$

$V_{s,c2} = 74312.489$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 420.00$

$s = 250.00$

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

$s/d = 0.56818182$

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

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$

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

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

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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 683214.917$

$b_w = 400.00$

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

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

From analysis, chord rotation  $\theta = 6.5739902E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.00499459$  ((4.29), Biskinis Phd))

$M_y = 7.0217E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3031.329

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4205E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.54545$

$N = 17151.026$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

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

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

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

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

$y_{ten} = 5.2949365E-006$

with  $f_y = 601.9953$

$d = 707.00$

$y = 0.19595022$

$A = 0.01014948$

$B = 0.00445989$

with  $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 17151.026$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.5451003E-005$

with  $f_c' (12.3, (ACI 440)) = 30.48734$

$f_c = 30.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e/A_c = 0.31291181$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 25742.96$

$y = 0.19514499$

$A = 0.01001989$

$B = 0.00440616$

with  $E_s = 200000.00$

CONFIRMATION:  $y = 0.19595022 < t/d$

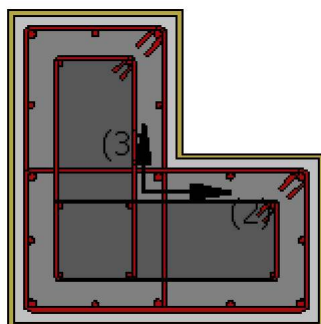
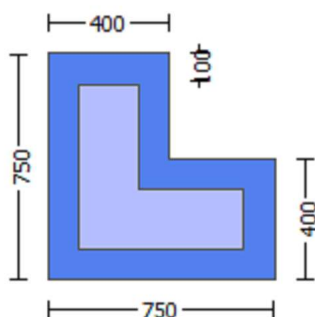
Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

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

## Calculation No. 2

column C1, Floor 1  
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)  
Analysis: Uniform +X  
Check: Chord rotation capacity (  $\phi$  )  
Edge: Start  
Local Axis: (2)



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

### Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
Concrete Elasticity,  $E_c = 25742.96$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
Concrete Elasticity,  $E_c = 23025.204$   
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,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.27105  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou,min} > 1$ )  
 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: 3  
 EDGE -A-  
 Shear Force,  $V_a = -0.000297$   
 EDGE -B-  
 Shear Force,  $V_b = 0.000297$   
 BOTH EDGES  
 Axial Force,  $F = -16273.615$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{sl,t} = 0.00$   
   -Compression:  $A_{sl,c} = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 1137.257$   
   -Compression:  $A_{sl,com} = 2208.54$   
   -Middle:  $A_{sl,mid} = 2007.478$

Calculation of Shear Capacity ratio ,  $V_e/V_r = 1.21726$   
 Member Controlled by Shear ( $V_e/V_r > 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$   
 with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 1.8183E+009$   
 $\mu_{u1+} = 1.5436E+009$ , 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  
 $\mu_{u1-} = 1.8183E+009$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 1.8183E+009$   
 $\mu_{u2+} = 1.5436E+009$ , 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  
 $\mu_{u2-} = 1.8183E+009$ , 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:

$$\mu = 5.2115571\text{E-}005$$

$$\text{Mu} = 1.5436\text{E+}009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_o) = 0.01596533$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01596533$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$$

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

$$f_x = 0.0465966$$

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

$$a_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$f_y = 0.0465966$$

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

$$a_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

$A_{\text{conf,min1}} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length

equal to half the clear spacing between external hoops.

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

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.31295$

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$psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$   
 $psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709$   
 Lstir1 (Length of stirrups along Y) = 2060.00  
 Astir1 (stirrups area) = 78.53982  
 $psh2 (5.4d) = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
 Lstir2 (Length of stirrups along Y) = 1468.00  
 Astir2 (stirrups area) = 50.26548

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$psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$   
 $psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709$   
 Lstir1 (Length of stirrups along X) = 2060.00  
 Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
 Lstir2 (Length of stirrups along X) = 1468.00  
 Astir2 (stirrups area) = 50.26548

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Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 896.8923

fy1 = 747.4102

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 747.4102

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

y2 = 0.0025

sh2 = 0.008

ft2 = 906.1344

fy2 = 755.112

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 755.112

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

yv = 0.0025

shv = 0.008

ftv = 902.993



```

fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = (fsjacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.13151351
Mu = MRc (4.15) = 1.5436E+009
u = su (4.1) = 5.2115571E-005

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu1-

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

```

u = 6.7707597E-005
Mu = 1.8183E+009

```

with full section properties:

```

b = 400.00
d = 707.00
d' = 43.00
v = 0.00191815
N = 16273.615
fc = 30.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01596533
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01596533
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.09711526
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

```

$$f_x = 0.0465966$$

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

$$a_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 860.3348$$

$$f_y = 0.0465966$$

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

$$a_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 860.3348$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_f = 0.015$$

$$a_{se} ((5.4d), \text{TBDY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

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

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

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

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

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

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.31295$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.31295$$

$$p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00367709$$

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

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

$$p_{sh2} ((5.4d), \text{TBDY}) = L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00067082$$

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

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

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.31295$$

$$p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00367709$$

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

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

$$p_{sh2} ((5.4d), \text{TBDY}) = L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00067082$$

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

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

```

Asec = 440000.00
s1 = 100.00
s2 = 250.00
fywe1 = 781.25
fywe2 = 656.25
fce = 30.00
From ((5.A.5), TBDY), TBDY: cc = 0.00471045
c = confinement factor = 1.27105
y1 = 0.0025
sh1 = 0.008
ft1 = 906.1344
fy1 = 755.112
su1 = 0.032
using (30) in Biskinis/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 = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 755.112
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 896.8923
fy2 = 747.4102
su2 = 0.032
using (30) in Biskinis/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 = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 747.4102
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045

```

$c = \text{confinement factor} = 1.27105$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.2415059$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12309166$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.21875854$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $s_u(4.8) = 0.3315127$   
 $M_u = M_{Rc}(4.15) = 1.8183E+009$   
 $u = s_u(4.1) = 6.7707597E-005$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of  $M_{u2+}$

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

$u = 5.2115571E-005$

$M_u = 1.5436E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00102302$

$N = 16273.615$

$f_c = 30.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_o) = 0.01596533$

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

From (5.4b), TB DY:  $\phi_u = 0.01596533$

$\phi_{we}((5.4c), \text{TB DY}) = a_{se} * \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.09711526$

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

$\phi_{fx} = 0.0465966$

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

$a_f = 0.31984848$

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

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A4.4.3(6),  $\phi_{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$\phi_{fy} = 0.0465966$

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

$a_f = 0.31984848$

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

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A4.4.3(6),  $\phi_{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.45746528$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

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

$$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.31295$$

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$$

$$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

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

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

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

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

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

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$$

$$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

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

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

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

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

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

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 781.25$$

$$f_{ywe2} = 656.25$$

$$f_{ce} = 30.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00471045$$

$$c = \text{confinement factor} = 1.27105$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 896.8923$$

$$fy1 = 747.4102$$

$$su1 = 0.032$$

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

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

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

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

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

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

```

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 747.4102
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 906.1344
fy2 = 755.112
su2 = 0.032
using (30) in Biskinis/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 = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 755.112
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.13151351
Mu = MRc (4.15) = 1.5436E+009
u = su (4.1) = 5.2115571E-005

```

Calculation of ratio lb/lb

Adequate Lap Length: lb/lb >= 1

Calculation of Mu2-

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

$$\phi_u = 6.7707597E-005$$

$$\mu_u = 1.8183E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$\nu = 0.00191815$$

$$N = 16273.615$$

$$f_c = 30.00$$

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

$$\text{Final value of } \phi_{cu}: \phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{co}) = 0.01596533$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01596533$$

$$\phi_{we} ((5.4c), TBDY) = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.09711526$$

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

$$\phi_{fx} = 0.0465966$$

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

$$a_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$\phi_{fy} = 0.0465966$$

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

$$a_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

$A_{\text{conf,min1}} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

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

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.31295$

---

$psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ (5.4d)} = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

$psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 906.1344

fy1 = 755.112

su1 = 0.032

using (30) in Biskinis/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 = 1.00

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

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

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

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

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 755.112

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

y2 = 0.0025

sh2 = 0.008

ft2 = 896.8923

fy2 = 747.4102

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 747.4102

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

yv = 0.0025

shv = 0.008

ftv = 902.993

fyv = 752.4941

suv = 0.032



using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $y_v$ ,  $sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs\_jacket * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 752.4941$   
with  $Esv = (Es\_jacket * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.1965694$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.10018826$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.1780546$   
and confined core properties:  
 $b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.2415059$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.12309166$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.21875854$   
Case/Assumption: Unconfined full section - Steel rupture  
'satisfies Eq. (4.3)  
--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
--->  
 $su (4.8) = 0.3315127$   
 $Mu = MRc (4.15) = 1.8183E+009$   
 $u = su (4.1) = 6.7707597E-005$

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

Adequate Lap Length:  $l_b/l_d \geq 1$   
-----  
-----  
-----

Calculation of Shear Strength  $V_r = Min(V_{r1}, V_{r2}) = 995834.294$   
-----

Calculation of Shear Strength at edge 1,  $V_{r1} = 995834.294$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$

$V_{Col0} = 995834.294$

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

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

$= 1$  (normal-weight concrete)

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.54545$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 30.3689$

$Vu = 0.000297$

$d = 0.8 * h = 600.00$

$Nu = 16273.615$

$Ag = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$

$V_{s,j1} = 589048.623$  is calculated for section web jacket, with:

$d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314159.265$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 92890.612$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$   
 $df_v = d$  (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:  $V_s + V_f \leq 836763.965$   
 $bw = 400.00$

-----  
 Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$   
 $V_{r2} = V_{Col}((10.3), ASCE 41-17) = knl \cdot V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $knl = 1$  (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:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 30.36921$   
 $V_u = 0.000297$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$

Vs,j1 = 589048.623 is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 625.00$$

$$s = 100.00$$

Vs,j1 is multiplied by Col,j1 = 1.00

$$s/d = 0.16666667$$

Vs,j2 = 314159.265 is calculated for section flange jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 625.00$$

$$s = 100.00$$

Vs,j2 is multiplied by Col,j2 = 1.00

$$s/d = 0.3125$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$$

Vs,c1 = 92890.612 is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 525.00$$

$$s = 250.00$$

Vs,c1 is multiplied by Col,c1 = 1.00

$$s/d = 0.56818182$$

Vs,c2 = 0.00 is calculated for section flange core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 525.00$$

$$s = 250.00$$

Vs,c2 is multiplied by Col,c2 = 0.00

$$s/d = 1.5625$$

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

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

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

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

This later relation, considered as a function  $V_f(\theta, a)$ , 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.

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

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

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 836763.965$$

$$b_w = 400.00$$

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

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

Constant Properties

$$\text{Knowledge Factor, } \gamma = 1.00$$

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

Consequently:

Jacket

$$\text{New material of Primary Member: Concrete Strength, } f_c = f_{cm} = 30.00$$

$$\text{New material of Primary Member: Steel Strength, } f_s = f_{sm} = 625.00$$

Concrete Elasticity,  $E_c = 25742.96$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
Concrete Elasticity,  $E_c = 23025.204$   
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,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
Existing Column  
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
#####  
Max Height,  $H_{max} = 750.00$   
Min Height,  $H_{min} = 400.00$   
Max Width,  $W_{max} = 750.00$   
Min Width,  $W_{min} = 400.00$   
Jacket Thickness,  $t_j = 100.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.27105  
Element Length,  $L = 3000.00$   
Primary Member  
Smooth Bars  
Ductile Steel  
With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Adequate Lap Length ( $l_o/l_{ou}, \min \geq 1$ )  
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = -0.00029699$   
EDGE -B-  
Shear Force,  $V_b = 0.00029699$   
BOTH EDGES  
Axial Force,  $F = -16273.615$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 5353.274$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 1137.257$   
-Compression:  $A_{st,com} = 2208.54$   
-Middle:  $A_{st,mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.21726$   
Member Controlled by Shear ( $V_e/V_r > 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$   
with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 1.8183E+009$

Mu1+ = 1.5436E+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- = 1.8183E+009, 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-) = 1.8183E+009

Mu2+ = 1.5436E+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- = 1.8183E+009, 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:

$\phi_u = 5.2115571E-005$

Mu = 1.5436E+009  
-----

with full section properties:

b = 750.00

d = 707.00

d' = 43.00

v = 0.00102302

N = 16273.615

fc = 30.00

co (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01596533$

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

From (5.4b), TBDY:  $\phi_u = 0.01596533$

we ((5.4c), TBDY) =  $\text{ase} * \text{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.09711526$

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

-----  
 $\phi_x = 0.0465966$

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

$\text{af} = 0.31984848$

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

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

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

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

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

-----  
 $f_y = 0.0465966$

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

$\text{af} = 0.31984848$

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

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

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

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

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

-----  
R = 40.00

Effective FRP thickness,  $t_f = \text{NL} * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$\text{ase} ((5.4d), \text{TBDY}) = (\text{ase1} * A_{\text{ext}} + \text{ase2} * A_{\text{int}})/A_{\text{sec}} = 0.45746528$

$\text{ase1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

Aconf,min1 = 293525.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 3.31295$

psh\_x\*Fywe =  $psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00367709$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d)) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe =  $psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00367709$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 896.8923

fy1 = 747.4102

su1 = 0.032

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

lo/lou,min =  $l_b/l_d = 1.00$

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

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

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

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

with fs1 =  $(f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 747.4102$

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

y2 = 0.0025

sh2 = 0.008

ft2 = 906.1344

fy2 = 755.112

su2 = 0.032

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

lo/lou,min =  $l_b/l_b,min = 1.00$

```

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 = 755.112
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
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 = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.13151351
Mu = MRc (4.15) = 1.5436E+009
u = su (4.1) = 5.2115571E-005

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

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

u = 6.7707597E-005  
Mu = 1.8183E+009

with full section properties:

b = 400.00  
d = 707.00  
d' = 43.00

$v = 0.00191815$   
 $N = 16273.615$   
 $f_c = 30.00$   
 $\alpha (5A.5, TBDY) = 0.002$   
 Final value of  $\alpha$ :  $\alpha = \text{shear\_factor} * \text{Max}(\alpha_c, \alpha) = 0.01596533$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\alpha_c = 0.01596533$   
 $\alpha (5.4c, TBDY) = \alpha_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$   
 where  $f = \alpha * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0465966$   
 Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$   
 $\alpha_f = 0.31984848$   
 with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$   
 $b_{\max} = 750.00$   
 $h_{\max} = 750.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{fe} = 860.3348$

$f_y = 0.0465966$   
 Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$   
 $\alpha_f = 0.31984848$   
 with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$   
 $b_{\max} = 750.00$   
 $h_{\max} = 750.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{fe} = 860.3348$

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL * t * \cos(\beta_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$

$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$   
 $\alpha_{se1} = \text{Max}(((A_{conf, \max 1} - A_{noConf1}) / A_{conf, \max 1}) * (A_{conf, \min 1} / A_{conf, \max 1}), 0) = 0.45746528$   
 The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf, \min 1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf, \max 1}$  by a length equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{conf, \max 2} - A_{noConf2}) / A_{conf, \max 2}) * (A_{conf, \min 2} / A_{conf, \max 2}), 0) = 0.45746528$   
 The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf, \max 2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf, \min 2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf, \max 2}$  by a length equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $p_{sh, \min} * F_{ywe} = \text{Min}(p_{sh, x} * F_{ywe}, p_{sh, y} * F_{ywe}) = 3.31295$

$p_{sh, x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.31295$   
 $p_{sh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$



Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 3.31295  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00367709  
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00067082  
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00  
s1 = 100.00  
s2 = 250.00

fywe1 = 781.25  
fywe2 = 656.25  
fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045  
c = confinement factor = 1.27105

y1 = 0.0025  
sh1 = 0.008  
ft1 = 906.1344  
fy1 = 755.112  
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 755.112

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

y2 = 0.0025  
sh2 = 0.008  
ft2 = 896.8923  
fy2 = 747.4102  
su2 = 0.032

using (30) in Biskinis/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 = 1.00

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

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 747.4102

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

yv = 0.0025  
shv = 0.008  
ftv = 902.993  
fyv = 752.4941  
suv = 0.032

using (30) in Biskinis/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 = 1.00

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

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 752.4941

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

$$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.1965694$$

$$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.10018826$$

$$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.1780546$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 38.13135$$

$$c_c (5A.5, TBDY) = 0.00471045$$

$$c = \text{confinement factor} = 1.27105$$

$$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.2415059$$

$$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.12309166$$

$$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.21875854$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

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

--->

$$s_u (4.8) = 0.3315127$$

$$\mu_u = M_{Rc} (4.15) = 1.8183E+009$$

$$u = s_u (4.1) = 6.7707597E-005$$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

Calculation of  $\mu_{u2+}$

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

$$u = 5.2115571E-005$$

$$\mu_u = 1.5436E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} \cdot \text{Max}(c_u, c_c) = 0.01596533$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01596533$$

$$w_e ((5.4c), TBDY) = a_{se} \cdot s_{h,min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$$

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)

$$f_x = 0.0465966$$

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

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$f_y = 0.0465966$$

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

$$a_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 860.3348$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$ase((5.4d), \text{TB DY}) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.45746528$$

$$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

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

$$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.31295$$

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.31295$$

$$p_{sh1}((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$$

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

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

$$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$$

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

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

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.31295$$

$$p_{sh1}((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$$

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

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

$$p_{sh2}((5.4d), \text{TB DY}) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$$

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

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

$$A_{sec} = 440000.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

$$f_{ywe1} = 781.25$$

$$f_{ywe2} = 656.25$$

$$f_{ce} = 30.00$$

$$\text{From ((5.A5), TB DY), TB DY: } cc = 0.00471045$$

$$c = \text{confinement factor} = 1.27105$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 896.8923$$

$$fy_1 = 747.4102$$

```

su1 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 747.4102
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 906.1344
fy2 = 755.112
su2 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 755.112
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
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 = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.13151351
Mu = MRc (4.15) = 1.5436E+009

```

$$u = s_u(4.1) = 5.2115571E-005$$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of  $\mu_2$

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

$$u = 6.7707597E-005$$

$$\mu = 1.8183E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00191815$$

$$N = 16273.615$$

$$f_c = 30.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, \mu_c) = 0.01596533$$

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

$$\text{From (5.4b), TB DY: } \mu = 0.01596533$$

$$\mu_c \text{ ((5.4c), TB DY) = } \alpha * \mu_{c, \min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$$

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

$$f_x = 0.0465966$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$f_y = 0.0465966$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TB DY) = } (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{conf, \max 1} - A_{noConf1})/A_{conf, \max 1}) * (A_{conf, \min 1}/A_{conf, \max 1}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and

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

$A_{conf, \min 1} = 293525.00$  is the confined core area at 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.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - \text{AnoConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and

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

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max2 by a length

equal to half the clear spacing between internal hoops.

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

$psh,min * F_{ywe} = \text{Min}(psh,x * F_{ywe}, psh,y * F_{ywe}) = 3.31295$

$psh,x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

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

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

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

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

$psh,y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

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

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

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

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

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

$c = \text{confinement factor} = 1.27105$

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 906.1344$

$fy1 = 755.112$

$su1 = 0.032$

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

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

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

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

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  $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 755.112$

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

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 896.8923$

$fy2 = 747.4102$

$su2 = 0.032$

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

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

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

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

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

For calculation of  $es_{u2\_nominal}$  and  $y_2$ ,  $sh_2$ ,  $ft_2$ ,  $fy_2$ , it is considered characteristic value  $fs_{y2} = fs_2/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 747.4102$

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

$y_v = 0.0025$   
 $sh_v = 0.008$   
 $ft_v = 902.993$   
 $fy_v = 752.4941$   
 $suv = 0.032$

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

$lo/lo_{u,min} = lb/ld = 1.00$   
 $suv = 0.4 \cdot es_{u\_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $es_{u\_nominal} = 0.08$ , considering characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY

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

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 752.4941$

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

$1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.1965694$   
 $2 = Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.10018826$   
 $v = Asl_{mid}/(b \cdot d) \cdot (fs_v/fc) = 0.1780546$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.2415059$   
 $2 = Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.12309166$   
 $v = Asl_{mid}/(b \cdot d) \cdot (fs_v/fc) = 0.21875854$

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

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->

$su (4.8) = 0.3315127$   
 $\mu_u = MR_c (4.15) = 1.8183E+009$   
 $u = su (4.1) = 6.7707597E-005$

---

Calculation of ratio  $lb/ld$

---

Adequate Lap Length:  $lb/ld \geq 1$

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Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 995834.294$

---

Calculation of Shear Strength at edge 1,  $V_{r1} = 995834.294$   
 $V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $knl = 1$  (zero step-static loading)

---

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

---

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.54545$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$   
 $\mu_u = 30.38488$   
 $V_u = 0.00029699$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 903207.888$   
 $V_{sj1} = 314159.265$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.3125$   
 $V_{sj2} = 589048.623$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 92890.612$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $knl = 1$  (zero step-static loading)

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

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.54545$ , but  $f_c'^{0.5} \leq$



8.3 MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 30.38458$

$V_u = 0.00029699$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.615$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 996098.499$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 903207.888$

$V_{sj1} = 314159.265$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 625.00$

$s = 100.00$

$V_{sj1}$  is multiplied by  $Col,j1 = 1.00$

$s/d = 0.3125$

$V_{sj2} = 589048.623$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 625.00$

$s = 100.00$

$V_{sj2}$  is multiplied by  $Col,j2 = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$

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

$d = 160.00$

$A_v = 100530.965$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.5625$

$V_{s,c2} = 92890.612$  is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 0.56818182$

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

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$  (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:  $V_s + V_f \leq 836763.965$

$b_w = 400.00$

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

At local axis: 2

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

At local axis: 2

Integration Section: (a)

Section Type: rcjics

## 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 Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_b/l_d \geq 1$ )

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

Bending Moment,  $M = -174480.279$

Shear Force,  $V_2 = -5348.301$

Shear Force,  $V_3 = 78.97309$

Axial Force,  $F = -17151.026$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 0.00$

-Compression:  $A_{sl,c} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1137.257$

-Compression:  $A_{sl,com} = 2208.54$

-Middle:  $A_{sl,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten,jacket} = 829.3805$

-Compression:  $A_{sl,com,jacket} = 1746.726$

-Middle:  $A_{sl,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten,core} = 307.8761$

-Compression:  $A_{sl,com,core} = 461.8141$

-Middle:  $A_{sl,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $\phi_R = \phi_u = 0.00570579$   
 $\phi_u = \phi_y + \phi_p = 0.00570579$

- Calculation of  $\phi_y$  -

$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00364028$  ((4.29), Biskinis Phd))  
 $M_y = 7.0217E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 2209.364  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4205E+014$   
 $factor = 0.30$   
 $A_g = 440000.00$   
Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.54545$   
 $N = 17151.026$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\phi_y$  and  $M_y$  according to Annex 7 -

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

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

$\phi_y = \text{Min}(\phi_{y,ten}, \phi_{y,com})$   
 $\phi_{y,ten} = 5.2949365E-006$   
with  $f_y = 601.9953$   
 $d = 707.00$   
 $\phi_y = 0.19595022$   
 $A = 0.01014948$   
 $B = 0.00445989$   
with  $p_t = 0.0064556$   
 $p_c = 0.00416509$   
 $p_v = 0.00378591$   
 $N = 17151.026$   
 $b = 750.00$   
 $\phi_y = 0.06082037$   
 $\phi_{y,comp} = 1.5451003E-005$   
with  $f_c' * (12.3, (ACI 440)) = 30.48734$   
 $f_c = 30.00$   
 $f_l = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $r_c = 40.00$   
 $A_e/A_c = 0.31291181$   
Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 25742.96$   
 $\phi_y = 0.19514499$   
 $A = 0.01001989$   
 $B = 0.00440616$   
with  $E_s = 200000.00$   
CONFIRMATION:  $\phi_y = 0.19595022 < t/d$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $l_b/d \geq 1$

- Calculation of  $p$  -

From table 10-8:  $p = 0.00206551$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/d \geq 1$   
shear control ratio  $V_{yE}/V_{CoIE} = 1.21726$

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

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

-  $t = s_1 + s_2 + 2 \cdot t_f/bw \cdot (f_{fe}/f_s) = 0.0064556$

jacket:  $s_1 = A_{v1} \cdot L_{\text{stir1}}/(s_1 \cdot A_g) = 0.00367709$

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

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

$s_1 = 100.00$

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

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

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

$s_2 = 250.00$

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

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

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

For the normalisation  $f_s$  of jacket is used.

$NUD = 17151.026$

$A_g = 440000.00$

$f_{cE} = (f_{c\_jacket} \cdot \text{Area\_jacket} + f_{c\_core} \cdot \text{Area\_core})/\text{section\_area} = 27.54545$

$f_{yIE} = (f_{y\_ext\_Long\_Reinf} \cdot \text{Area\_ext\_Long\_Reinf} + f_{y\_int\_Long\_Reinf} \cdot \text{Area\_int\_Long\_Reinf})/\text{Area\_Tot\_Long\_Rein} = 601.9953$

$f_{yIE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2)/(s_1 + s_2) = 609.5715$

$p_l = \text{Area\_Tot\_Long\_Rein}/(b \cdot d) = 0.01009575$

$b = 750.00$

$d = 707.00$

$f_{cE} = 27.54545$

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

At local axis: 2

Integration Section: (a)

### Calculation No. 3

column C1, Floor 1

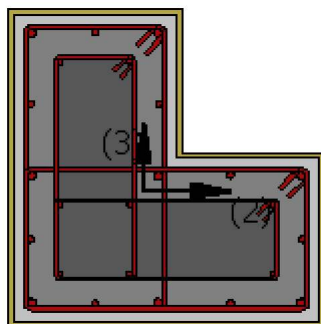
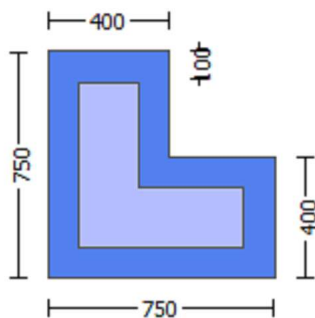
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rcjlcs

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 Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$

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

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_c = f_{cm} = 30.00$

New material: Steel Strength,  $f_s = f_{sm} = 625.00$

Existing Column

Existing material: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )

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°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

#### Stepwise Properties

EDGE -A-  
Bending Moment, Ma = -174480.279  
Shear Force, Va = 78.97309  
EDGE -B-  
Bending Moment, Mb = -60775.497  
Shear Force, Vb = -78.97309  
BOTH EDGES  
Axial Force, F = -17151.026  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 5353.274  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 1137.257  
-Compression: Asl,com = 2208.54  
-Middle: Asl,mid = 2007.478  
Mean Diameter of Tension Reinforcement, DbL,ten = 16.80

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity VR = \*Vn = 824716.927  
Vn ((10.3), ASCE 41-17) = knl\*VColO = 824716.927  
VCol = 824716.927  
knl = 1.00  
displacement\_ductility\_demand = 0.00705404

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 = 18.36364, but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
M/Vd = 3.68227  
Mu = 174480.279  
Vu = 78.97309  
d = 0.8\*h = 600.00  
Nu = 17151.026  
Ag = 300000.00  
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 796878.80  
where:  
Vs,jacket = Vs,j1 + Vs,j2 = 722566.31  
Vs,j1 = 471238.898 is calculated for section web jacket, with:  
d = 600.00  
Av = 157079.633  
fy = 500.00  
s = 100.00  
Vs,j1 is multiplied by Col,j1 = 1.00  
s/d = 0.16666667  
Vs,j2 = 251327.412 is calculated for section flange jacket, with:  
d = 320.00  
Av = 157079.633  
fy = 500.00  
s = 100.00  
Vs,j2 is multiplied by Col,j2 = 1.00  
s/d = 0.3125  
Vs,core = Vs,c1 + Vs,c2 = 74312.489  
Vs,c1 = 74312.489 is calculated for section web core, with:  
d = 440.00  
Av = 100530.965

$f_y = 420.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 420.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$   
 $df_v = d$  (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:  $V_s + V_f \leq 683214.917$   
 $bw = 400.00$

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

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

From analysis, chord rotation  $\theta = 2.5678666E-005$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00364028$  ((4.29), Biskinis Phd))  
 $M_y = 7.0217E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 2209.364  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.4205E+014$   
 $\text{factor} = 0.30$   
 $A_g = 440000.00$   
 Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.54545$   
 $N = 17151.026$   
 $E_c \cdot I_g = E_{c,\text{jacket}} \cdot I_{g,\text{jacket}} + E_{c,\text{core}} \cdot I_{g,\text{core}} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

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

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

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

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 5.2949365E-006$   
 with  $f_y = 601.9953$   
 $d = 707.00$   
 $y = 0.19595022$   
 $A = 0.01014948$   
 $B = 0.00445989$   
 with  $pt = 0.00214476$   
 $pc = 0.00416509$

$p_v = 0.00378591$   
 $N = 17151.026$   
 $b = 750.00$   
 $" = 0.06082037$   
 $y_{comp} = 1.5451003E-005$   
 with  $f_c^* (12.3, (ACI 440)) = 30.48734$   
 $f_c = 30.00$   
 $f_l = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $rc = 40.00$   
 $A_e/A_c = 0.31291181$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 25742.96$   
 $y = 0.19514499$   
 $A = 0.01001989$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.19595022 < t/d$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

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

At local axis: 3

Integration Section: (a)

## Calculation No. 4

column C1, Floor 1

Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

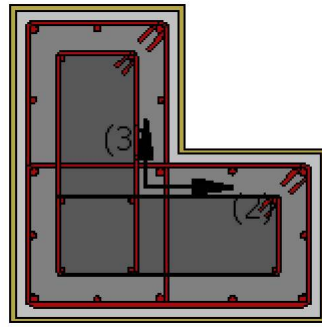
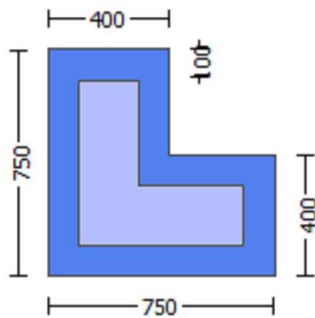
Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

Edge: Start

Local Axis: (3)





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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.27105

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $ef_u = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $bi: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -0.000297$

EDGE -B-

Shear Force,  $V_b = 0.000297$

BOTH EDGES

Axial Force,  $F = -16273.615$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.21726$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$  with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.8183E+009$

$\mu_{1+} = 1.5436E+009$ , 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

$\mu_{1-} = 1.8183E+009$ , 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.8183E+009$

$\mu_{2+} = 1.5436E+009$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 1.8183E+009$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $\mu_{1+}$

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

$\mu = 5.2115571E-005$

$M_u = 1.5436E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00102302$

$N = 16273.615$

$f_c = 30.00$

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

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_s) = 0.01596533$

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

From (5.4b), TBDY:  $\mu_c = 0.01596533$

we ((5.4c), TBDY) =  $a_s * \frac{f_{ywe}}{f_{ce}} + \text{Min}(f_x, f_y) = 0.09711526$

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

$f_x = 0.0465966$

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

$a_f = 0.31984848$

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

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00508$   
 $bw = 400.00$   
effective stress from (A.35),  $ff,e = 860.3348$

$f_y = 0.0465966$

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

$af = 0.31984848$

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

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff,e = 860.3348$

$R = 40.00$

Effective FRP thickness,  $tf = NL \cdot t \cdot \cos(b1) = 1.016$

$f_u, f = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$

$ase ((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.45746528$

$ase1 = \text{Max}(((A_{conf, \max 1} - A_{noConf1}) / A_{conf, \max 1}) \cdot (A_{conf, \min 1} / A_{conf, \max 1}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf, \min 1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf, \max 1}$  by a length equal to half the clear spacing between external hoops.

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

$ase2 (>= ase1) = \text{Max}(((A_{conf, \max 2} - A_{noConf2}) / A_{conf, \max 2}) \cdot (A_{conf, \min 2} / A_{conf, \max 2}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf, \max 2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf, \min 2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf, \max 2}$  by a length equal to half the clear spacing between internal hoops.

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

$psh_{\min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$

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

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

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

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

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

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$

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

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

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

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

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

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$   
 From ((5.A.5), TBDY), TBDY:  $cc = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $y_1 = 0.0025$   
 $sh_1 = 0.008$   
 $ft_1 = 896.8923$   
 $fy_1 = 747.4102$   
 $su_1 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 1.00$   
 $su_1 = 0.4 * esu_1, \text{nominal} ((5.5), \text{TBDY}) = 0.032$   
 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.  
 with  $fs_1 = (fs, \text{jacket} * Asl, \text{ten, jacket} + fs, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 747.4102$   
 with  $Es_1 = (Es, \text{jacket} * Asl, \text{ten, jacket} + Es, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$   
 $y_2 = 0.0025$   
 $sh_2 = 0.008$   
 $ft_2 = 906.1344$   
 $fy_2 = 755.112$   
 $su_2 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/lb, \min = 1.00$   
 $su_2 = 0.4 * esu_2, \text{nominal} ((5.5), \text{TBDY}) = 0.032$   
 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.  
 with  $fs_2 = (fs, \text{jacket} * Asl, \text{com, jacket} + fs, \text{core} * Asl, \text{com, core}) / Asl, \text{com} = 755.112$   
 with  $Es_2 = (Es, \text{jacket} * Asl, \text{com, jacket} + Es, \text{core} * Asl, \text{com, core}) / Asl, \text{com} = 200000.00$   
 $y_v = 0.0025$   
 $sh_v = 0.008$   
 $ft_v = 902.993$   
 $fy_v = 752.4941$   
 $suv = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/ld = 1.00$   
 $suv = 0.4 * esuv, \text{nominal} ((5.5), \text{TBDY}) = 0.032$   
 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.  
 with  $fsv = (fs, \text{jacket} * Asl, \text{mid, jacket} + fs, \text{mid} * Asl, \text{mid, core}) / Asl, \text{mid} = 752.4941$   
 with  $Es_v = (Es, \text{jacket} * Asl, \text{mid, jacket} + Es, \text{mid} * Asl, \text{mid, core}) / Asl, \text{mid} = 200000.00$   
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / f_c) = 0.05343374$   
 $2 = Asl, \text{com} / (b * d) * (fs_2 / f_c) = 0.10483702$   
 $v = Asl, \text{mid} / (b * d) * (fsv / f_c) = 0.09496245$   
 and confined core properties:  
 $b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, \text{TBDY}) = 38.13135$   
 $cc (5A.5, \text{TBDY}) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / f_c) = 0.06065386$   
 $2 = Asl, \text{com} / (b * d) * (fs_2 / f_c) = 0.11900291$   
 $v = Asl, \text{mid} / (b * d) * (fsv / f_c) = 0.10779406$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $\mu_u(4.8) = 0.13151351$   
 $M_u = M_{Rc}(4.15) = 1.5436E+009$   
 $u = \mu_u(4.1) = 5.2115571E-005$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

Calculation of  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu_u = 6.7707597E-005$   
 $M_u = 1.8183E+009$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00191815$   
 $N = 16273.615$

$f_c = 30.00$   
 $\alpha(5A.5, TBDY) = 0.002$

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \alpha) = 0.01596533$

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

From (5.4b), TBDY:  $\mu_u = 0.01596533$

$\mu_{ue}((5.4c), TBDY) = \alpha * \text{sh\_min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$

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

$f_x = 0.0465966$

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

$\alpha_f = 0.31984848$

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

$b_{max} = 750.00$

$h_{max} = 750.00$

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

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$f_y = 0.0465966$

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

$\alpha_f = 0.31984848$

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

$b_{max} = 750.00$

$h_{max} = 750.00$

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

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

$\alpha_{se}((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

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

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.31295$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

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

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

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

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

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

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

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

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

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

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

$c = \text{confinement factor} = 1.27105$

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 906.1344$

$fy1 = 755.112$

$su1 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_d = 1.00$

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

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

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

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

with  $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 755.112$

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

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 896.8923$

$fy2 = 747.4102$

```

su2 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 747.4102
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
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 = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is not satisfied
---->
v < vs,c - RHS eq.(4.5) is satisfied
---->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu2+

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

u = 5.2115571E-005

Mu = 1.5436E+009

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01596533$$

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

$$\text{From (5.4b), TB DY: } \alpha = 0.01596533$$

$$\alpha_c ((5.4c), \text{TB DY}) = \alpha_{se} * \alpha_{h,min} * f_{ywe} / f_{ce} + \text{Min}(\alpha_x, \alpha_y) = 0.09711526$$

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

$$\alpha_x = 0.0465966$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$\alpha_y = 0.0465966$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

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

$$f_u, f = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$\alpha_{se} ((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

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

$$\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

$$p_{sh,min} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 3.31295$$



$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

$Asec = 440000.00$   
 $s1 = 100.00$   
 $s2 = 250.00$   
 $fywe1 = 781.25$   
 $fywe2 = 656.25$   
 $fce = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$

$y1 = 0.0025$   
 $sh1 = 0.008$   
 $ft1 = 896.8923$   
 $fy1 = 747.4102$   
 $su1 = 0.032$

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

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

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

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

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

with  $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 747.4102$

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

$y2 = 0.0025$   
 $sh2 = 0.008$   
 $ft2 = 906.1344$   
 $fy2 = 755.112$   
 $su2 = 0.032$

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

$lo/lou,min = lb/lb,min = 1.00$

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

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.

$y2, sh2, ft2, fy2$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 755.112$

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

$yv = 0.0025$   
 $shv = 0.008$   
 $ftv = 902.993$   
 $fyv = 752.4941$   
 $suv = 0.032$

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

$lo/lou,min = lb/ld = 1.00$

$suv = 0.4 * esuv\_nominal \text{ ((5.5), TBDY)} = 0.032$

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

with  $f_{sv} = (f_{s,jacket} \cdot A_{sl,mid,jacket} + f_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 752.4941$

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

$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.05343374$

$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.10483702$

$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.09496245$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} \text{ (5A.2, TBDY)} = 38.13135$

$cc \text{ (5A.5, TBDY)} = 0.00471045$

$c = \text{confinement factor} = 1.27105$

$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.06065386$

$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.11900291$

$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.10779406$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

---->

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

---->

$su \text{ (4.8)} = 0.13151351$

$Mu = MRc \text{ (4.15)} = 1.5436E+009$

$u = su \text{ (4.1)} = 5.2115571E-005$

Calculation of ratio  $lb/ld$

Adequate Lap Length:  $lb/ld \geq 1$

Calculation of  $Mu_2$ -

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

$u = 6.7707597E-005$

$Mu = 1.8183E+009$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00191815$

$N = 16273.615$

$f_c = 30.00$

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

Final value of  $cu$ :  $cu^* = \text{shear\_factor} \cdot \text{Max}(cu, cc) = 0.01596533$

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

From (5.4b), TBDY:  $cu = 0.01596533$

we ((5.4c), TBDY) =  $ase \cdot sh_{min} \cdot fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.09711526$

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

$fx = 0.0465966$

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

$af = 0.31984848$

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

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $f_{f,e} = 860.3348$

$f_y = 0.0465966$

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

$a_f = 0.31984848$

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

$b_{\max} = 750.00$

$h_{\max} = 750.00$

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

$b_w = 400.00$

effective stress from (A.35),  $f_{f,e} = 860.3348$

$R = 40.00$

Effective FRP thickness,  $t_f = N_L \cdot t \cdot \cos(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$a_{se} ((5.4d), TBDY) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int})/A_{sec} = 0.45746528$

$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) \cdot (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

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

equal to half the clear spacing between external hoops.

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

$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) \cdot (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

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

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

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

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 3.31295$

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 3.31295$

$p_{sh1} ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$

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

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

$p_{sh2} ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$

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

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

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 3.31295$

$p_{sh1} ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$

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

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

$p_{sh2} ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$

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

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

$A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

```

c = confinement factor = 1.27105
y1 = 0.0025
sh1 = 0.008
ft1 = 906.1344
fy1 = 755.112
su1 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 755.112
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 896.8923
fy2 = 747.4102
su2 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 747.4102
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
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 = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied

```

```

--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005
-----

Calculation of ratio lb/ld
-----

Adequate Lap Length: lb/ld >= 1
-----
-----
-----

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 995834.294
-----

Calculation of Shear Strength at edge 1, Vr1 = 995834.294
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO
VColO = 995834.294
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*Areajacket + fc'core*Areacore)/Areasection = 27.54545, but fc'0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 30.3689
Vu = 0.000297
d = 0.8*h = 600.00
Nu = 16273.615
Ag = 300000.00
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 996098.499
where:
Vs,jacket = Vs,j1 + Vs,j2 = 903207.888
Vs,j1 = 589048.623 is calculated for section web jacket, with:
d = 600.00
Av = 157079.633
fy = 625.00
s = 100.00
Vs,j1 is multiplied by Col,j1 = 1.00
s/d = 0.16666667
Vs,j2 = 314159.265 is calculated for section flange jacket, with:
d = 320.00
Av = 157079.633
fy = 625.00
s = 100.00
Vs,j2 is multiplied by Col,j2 = 1.00
s/d = 0.3125
Vs,core = Vs,c1 + Vs,c2 = 92890.612
Vs,c1 = 92890.612 is calculated for section web core, with:
d = 440.00
Av = 100530.965
fy = 525.00
s = 250.00
Vs,c1 is multiplied by Col,c1 = 1.00
s/d = 0.56818182
Vs,c2 = 0.00 is calculated for section flange core, with:
d = 160.00
Av = 100530.965
fy = 525.00
s = 250.00
Vs,c2 is multiplied by Col,c2 = 0.00
s/d = 1.5625
Vf ((11-3)-(11.4), ACI 440) = 372533.843

```

$f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$   
 $V_{r2} = V_{Col}((10.3), \text{ASCE 41-17}) = knl * V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $knl = 1$  (zero step-static loading)

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

$\gamma = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * \text{Area}_{jacket} + f'_{c,core} * \text{Area}_{core}) / \text{Area}_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 30.36921$   
 $\nu_u = 0.000297$   
 $d = 0.8 * h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$   
 $V_{s,j1} = 589048.623$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314159.265$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 92890.612$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$

$V_f((11-3)-(11.4), \text{ACI } 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$   
 $df_v = d$  (figure 11.2, ACI 440) = 707.00  
 $ffe((11-5), \text{ACI } 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $bw = 400.00$

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

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

#### Constant Properties

Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
 Concrete Elasticity,  $E_c = 23025.204$   
 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,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.27105  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou, \min} \geq 1$ )

#### FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -0.00029699$

EDGE -B-

Shear Force,  $V_b = 0.00029699$

BOTH EDGES

Axial Force,  $F = -16273.615$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.21726$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$  with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.8183E+009$

$\mu_{1+} = 1.5436E+009$ , 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

$\mu_{1-} = 1.8183E+009$ , 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.8183E+009$

$\mu_{2+} = 1.5436E+009$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 1.8183E+009$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $\mu_{1+}$

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

$\phi_u = 5.2115571E-005$

$\mu_u = 1.5436E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00102302$

$N = 16273.615$

$f_c = 30.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01596533$

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



From (5.4b), TBDY:  $c_u = 0.01596533$   
 $w_e ((5.4c), TBDY) = a_{se} \cdot s_{h,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$   
 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)

---


$$f_x = 0.0465966$$

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

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

---


$$f_y = 0.0465966$$

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

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

---


$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$a_{se} ((5.4d), TBDY) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int})/A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) \cdot (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

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

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) \cdot (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

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

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

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

$$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 3.31295$$

---


$$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 3.31295$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$$

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

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

$$p_{sh2} ((5.4d)) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$$

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

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

---


$$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 3.31295$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$$

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

$A_{stir1}$  (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2)$  = 0.00067082  
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec}$  = 440000.00

$s1$  = 100.00

$s2$  = 250.00

$f_{ywe1}$  = 781.25

$f_{ywe2}$  = 656.25

$f_{ce}$  = 30.00

From ((5.A5), TBDY), TBDY:  $c_c$  = 0.00471045

$c$  = confinement factor = 1.27105

$y1$  = 0.0025

$sh1$  = 0.008

$ft1$  = 896.8923

$fy1$  = 747.4102

$su1$  = 0.032

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

$lo/lou,min$  =  $lb/ld$  = 1.00

$su1$  =  $0.4 * esu1\_nominal$  ((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  $fs1$  =  $(fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten}$  = 747.4102

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

$y2$  = 0.0025

$sh2$  = 0.008

$ft2$  = 906.1344

$fy2$  = 755.112

$su2$  = 0.032

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

$lo/lou,min$  =  $lb/lb,min$  = 1.00

$su2$  =  $0.4 * esu2\_nominal$  ((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  $fs2$  =  $(fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com}$  = 755.112

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

$yv$  = 0.0025

$shv$  = 0.008

$ftv$  = 902.993

$fyv$  = 752.4941

$suv$  = 0.032

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

$lo/lou,min$  =  $lb/ld$  = 1.00

$suv$  =  $0.4 * esuv\_nominal$  ((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  $fsv$  =  $(fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid}$  = 752.4941

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

$1 = A_{sl,ten} / (b * d) * (fs1 / f_c)$  = 0.05343374

$2 = A_{sl,com} / (b * d) * (fs2 / f_c)$  = 0.10483702

$v = A_{sl,mid} / (b * d) * (fsv / f_c)$  = 0.09496245

and confined core properties:

$b$  = 690.00

$d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.06065386$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11900291$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.10779406$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->

$su (4.8) = 0.13151351$   
 $Mu = MR_c (4.15) = 1.5436E+009$   
 $u = su (4.1) = 5.2115571E-005$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of  $Mu1$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 6.7707597E-005$   
 $Mu = 1.8183E+009$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00191815$   
 $N = 16273.615$   
 $f_c = 30.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01596533$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01596533$   
 $w_e ((5.4c), TBDY) = a_{se} * sh_{min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$   
 where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0465966$

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

$a_f = 0.31984848$

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

$b_{max} = 750.00$

$h_{max} = 750.00$

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

$b_w = 400.00$

effective stress from (A.35),  $f_{f,e} = 860.3348$

$f_y = 0.0465966$

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

$a_f = 0.31984848$

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

$b_{max} = 750.00$

$h_{max} = 750.00$

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

$b_w = 400.00$

effective stress from (A.35),  $f_{f,e} = 860.3348$

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_f = 0.015$   
 $ase((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.45746528$   
 $ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (\geq ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$   
 $psh1((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2(5.4d) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$   
 $psh1((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2((5.4d), TBDY) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$   
 $s1 = 100.00$   
 $s2 = 250.00$   
 $f_{ywe1} = 781.25$   
 $f_{ywe2} = 656.25$   
 $f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$   
 $c$  = confinement factor = 1.27105

$y1 = 0.0025$   
 $sh1 = 0.008$   
 $ft1 = 906.1344$   
 $fy1 = 755.112$   
 $su1 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $l_o / l_{ou,min} = l_b / l_d = 1.00$   
 $su1 = 0.4 \cdot esu1_{nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = (fs\_jacket \cdot Asl\_ten\_jacket + fs\_core \cdot Asl\_ten\_core) / Asl\_ten = 755.112$   
with  $Es1 = (Es\_jacket \cdot Asl\_ten\_jacket + Es\_core \cdot Asl\_ten\_core) / Asl\_ten = 200000.00$   
 $y2 = 0.0025$   
 $sh2 = 0.008$   
 $ft2 = 896.8923$   
 $fy2 = 747.4102$   
 $su2 = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/lb, min = 1.00$   
 $su2 = 0.4 \cdot esu2\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs2 = (fs\_jacket \cdot Asl\_com\_jacket + fs\_core \cdot Asl\_com\_core) / Asl\_com = 747.4102$   
with  $Es2 = (Es\_jacket \cdot Asl\_com\_jacket + Es\_core \cdot Asl\_com\_core) / Asl\_com = 200000.00$   
 $yv = 0.0025$   
 $shv = 0.008$   
 $ftv = 902.993$   
 $fyv = 752.4941$   
 $suv = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/ld = 1.00$   
 $suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs\_jacket \cdot Asl\_mid\_jacket + fs\_mid \cdot Asl\_mid\_core) / Asl\_mid = 752.4941$   
with  $Esv = (Es\_jacket \cdot Asl\_mid\_jacket + Es\_mid \cdot Asl\_mid\_core) / Asl\_mid = 200000.00$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.1965694$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.10018826$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.1780546$   
and confined core properties:  
 $b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.2415059$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.12309166$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.21875854$   
Case/Assumption: Unconfined full section - Steel rupture  
'satisfies Eq. (4.3)  
--->  
 $v < vs, y2$  - LHS eq.(4.5) is not satisfied  
--->  
 $v < vs, c$  - RHS eq.(4.5) is satisfied  
--->  
 $su (4.8) = 0.3315127$   
 $Mu = MRc (4.15) = 1.8183E+009$   
 $u = su (4.1) = 6.7707597E-005$

Calculation of ratio  $lb/ld$

Adequate Lap Length:  $lb/ld \geq 1$

## Calculation of $\mu_{2+}$

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

$$\mu = 5.2115571\text{E-}005$$

$$\mu_{\mu} = 1.5436\text{E+}009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha_{\text{co}}) = 0.01596533$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01596533$$

$$\mu_{\text{we}} ((5.4c), \text{TBDY}) = \alpha_{\text{se}} * \mu_{\text{min}} * f_{y\text{we}} / f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.09711526$$

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

$$\mu_x = 0.0465966$$

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

$$\alpha_f = 0.31984848$$

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

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

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

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$\mu_y = 0.0465966$$

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

$$\alpha_f = 0.31984848$$

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

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

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

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$\alpha_{\text{se}} ((5.4d), \text{TBDY}) = (\alpha_{\text{se1}} * A_{\text{ext}} + \alpha_{\text{se2}} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\alpha_{\text{se1}} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

$A_{\text{conf,min1}} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

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

$$\alpha_{\text{se2}} (>= \alpha_{\text{se1}}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.31295$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

$c$  = confinement factor = 1.27105

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 896.8923$

$fy1 = 747.4102$

$su1 = 0.032$

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

$lo/lo_{min} = lb/l_d = 1.00$

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

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

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

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

with  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 747.4102$

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

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 906.1344$

$fy2 = 755.112$

$su2 = 0.032$

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

$lo/lo_{min} = lb/l_b, min = 1.00$

$su2 = 0.4 * esu2_{nominal}$  ((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  $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 755.112$

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

$yv = 0.0025$

```

shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
    using (30) in Biskinis/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 = 1.00
    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 = 752.4941
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
    2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
    v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
    c = confinement factor = 1.27105
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
    2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
    v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.13151351
Mu = MRc (4.15) = 1.5436E+009
u = su (4.1) = 5.2115571E-005

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

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

u = 6.7707597E-005  
Mu = 1.8183E+009

with full section properties:

```

b = 400.00
d = 707.00
d' = 43.00
v = 0.00191815
    N = 16273.615
fc = 30.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01596533
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01596533
    we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.09711526

```



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

$$f_x = 0.0465966$$

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

$$af = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff_e = 860.3348$$

$$f_y = 0.0465966$$

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

$$af = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff_e = 860.3348$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase_1 \cdot A_{ext} + ase_2 \cdot A_{int})/A_{sec} = 0.45746528$$

$$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) \cdot (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

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

$$ase_2 (\geq ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) \cdot (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

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

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

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

$$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$$

$$psh_x \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 3.31295$$

$$psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$$

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

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

$$psh_2 \text{ (5.4d)} = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$$

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

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

$$psh_y \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 3.31295$$

$$psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$$

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

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

$$psh_2 \text{ ((5.4d), TBDY)} = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$$

Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 906.1344

fy1 = 755.112

su1 = 0.032

using (30) in Biskinis/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 = 1.00

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

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

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

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

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 755.112

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

y2 = 0.0025

sh2 = 0.008

ft2 = 896.8923

fy2 = 747.4102

su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

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

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

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

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 747.4102

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

yv = 0.0025

shv = 0.008

ftv = 902.993

fyv = 752.4941

suv = 0.032

using (30) in Biskinis/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 = 1.00

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

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

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

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

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 752.4941

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

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.1965694

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.10018826

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.1780546

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00

```

fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005

```

Calculation of ratio lb/l<sub>d</sub>

Adequate Lap Length: lb/l<sub>d</sub> >= 1

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 995834.294$

Calculation of Shear Strength at edge 1,  $V_{r1} = 995834.294$

$V_{r1} = V_{Col} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 995834.294$

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

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

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_c_{\text{jacket}} * \text{Area}_{\text{jacket}} + f'_c_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 30.38488$

$V_u = 0.00029699$

$d = 0.8 * h = 600.00$

$N_u = 16273.615$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 996098.499$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 903207.888$

$V_{sj1} = 314159.265$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 625.00$

$s = 100.00$

$V_{sj1}$  is multiplied by  $Col_{j1} = 1.00$

$s/d = 0.3125$

$V_{sj2} = 589048.623$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 625.00$

$s = 100.00$

$V_{sj2}$  is multiplied by  $Col_{j2} = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$

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

$d = 160.00$

$A_v = 100530.965$

$f_y = 525.00$

$s = 250.00$

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

$$s/d = 1.5625$$

$V_{s,c2} = 92890.612$  is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 525.00$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

$f = 0.95$ , for fully-wrapped sections

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

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

This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $\theta$ , 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,  $tf1 = NL \cdot t / \text{NoDir} = 1.016$

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

$ffe ((11-5), ACI 440) = 259.312$

$$E_f = 64828.00$$

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

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

From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$

$$bw = 400.00$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$

$$V_{Col0} = 995834.294$$

$knl = 1$  (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:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 30.38458$$

$$V_u = 0.00029699$$

$$d = 0.8 \cdot h = 600.00$$

$$N_u = 16273.615$$

$$A_g = 300000.00$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$

$V_{s,j1} = 314159.265$  is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 625.00$$

$$s = 100.00$$

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

$$s/d = 0.3125$$

$V_{s,j2} = 589048.623$  is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 625.00$$

$$s = 100.00$$

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

$$s/d = 0.16666667$$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$

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

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 525.00$$

$s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 92890.612$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In  $(11.3) \sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe}((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $b_w = 400.00$

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

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

Constant Properties

-----  
 Knowledge Factor,  $\gamma = 1.00$   
 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 Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
 Concrete Elasticity,  $E_c = 23025.204$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_b/l_d \geq 1$ )

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

Bending Moment,  $M = -1.6212E+007$

Shear Force,  $V_2 = -5348.301$

Shear Force,  $V_3 = 78.97309$

Axial Force,  $F = -17151.026$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{ten} = 1137.257$

-Compression:  $As_{com} = 2208.54$

-Middle:  $As_{mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{ten,jacket} = 829.3805$

-Compression:  $As_{com,jacket} = 1746.726$

-Middle:  $As_{mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{ten,core} = 307.8761$

-Compression:  $As_{com,core} = 461.8141$

-Middle:  $As_{mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = \frac{1}{2} u = 0.0070601$

$u = y + p = 0.0070601$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00499459$  ((4.29), Biskinis Phd))

$M_y = 7.0217E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3031.329

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4205E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.54545$

$N = 17151.026$

$E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

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

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

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

```

y = Min( y_ten, y_com)
y_ten = 5.2949365E-006
with fy = 601.9953
d = 707.00
y = 0.19595022
A = 0.01014948
B = 0.00445989
with pt = 0.0064556
pc = 0.00416509
pv = 0.00378591
N = 17151.026
b = 750.00
" = 0.06082037
y_comp = 1.5451003E-005
with fc* (12.3, (ACI 440)) = 30.48734
fc = 30.00
fl = 0.49678681
b = bmax = 750.00
h = hmax = 750.00
Ag = 0.44
g = pt + pc + pv = 0.01009575
rc = 40.00
Ae/Ac = 0.31291181
Effective FRP thickness, tf = NL*t*cos(b1) = 1.016
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 25742.96
y = 0.19514499
A = 0.01001989
B = 0.00440616
with Es = 200000.00
CONFIRMATION: y = 0.19595022 < t/d

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

- Calculation of p -

From table 10-8: p = 0.00206551

with:

- Columns not controlled by inadequate development or splicing along the clear height because lb/d >= 1

shear control ratio  $V_y E / V_{col} E = 1.21726$

d = d\_external = 707.00

s = s\_external = 0.00

-  $t = s_1 + s_2 + 2*tf/bw*(ffe/fs) = 0.0064556$

jacket:  $s_1 = A_{v1}*L_{stir1}/(s_1*Ag) = 0.00367709$

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

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

$s_1 = 100.00$

core:  $s_2 = A_{v2}*L_{stir2}/(s_2*Ag) = 0.00067082$

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

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

$s_2 = 250.00$

The term  $2*tf/bw*(ffe/fs)$  is implemented to account for FRP contribution

where  $f = 2*tf/bw$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $ffe/fs$  normalises f to steel strength

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

For the normalisation fs of jacket is used.

NUD = 17151.026

Ag = 440000.00

$f_{cE} = (f_{c\_jacket}*Area\_jacket + f_{c\_core}*Area\_core)/section\_area = 27.54545$

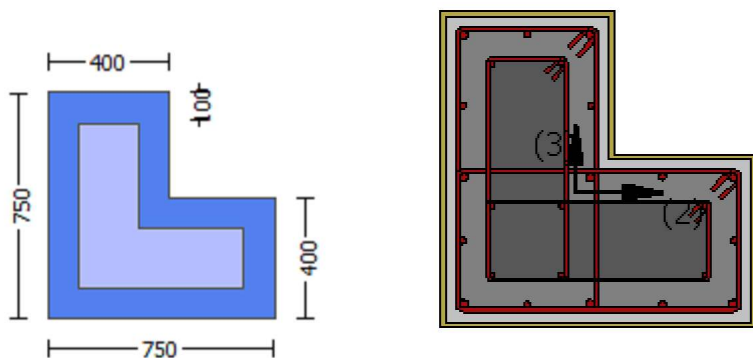
$f_{yE} = (f_{y\_ext\_Long\_Reinf}*Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf}*Area\_int\_Long\_Reinf)/Area\_Tot\_Long\_Reinf = 601.9953$

$f_{ytE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 609.5715$   
 $p_l = Area\_Tot\_Long\_Rein / (b \cdot d) = 0.01009575$   
 $b = 750.00$   
 $d = 707.00$   
 $f_{cE} = 27.54545$

-----  
 End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
 At local axis: 3  
 Integration Section: (a)

## Calculation No. 5

column C1, Floor 1  
 Limit State: Operational Level (data interpolation between analysis steps 1 and 2)  
 Analysis: Uniform +X  
 Check: Shear capacity  $VR_d$   
 Edge: End  
 Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjls

Constant Properties

-----  
 Knowledge Factor,  $= 1.00$   
 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 Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
 Concrete Elasticity,  $E_c = 25742.96$



```

Steel Elasticity, Es = 200000.00
Existing Column
Existing material of Primary Member: Concrete Strength, fc = fc_lower_bound = 16.00
Existing material of Primary Member: Steel Strength, fs = fs_lower_bound = 420.00
Concrete Elasticity, Ec = 23025.204
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of  $\mu_y$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, fc = fcm = 30.00
New material: Steel Strength, fs = fsm = 625.00
Existing Column
Existing material: Concrete Strength, fc = fcm = 24.00
Existing material: Steel Strength, fs = fsm = 525.00
#####
Max Height, Hmax = 750.00
Min Height, Hmin = 400.00
Max Width, Wmax = 750.00
Min Width, Wmin = 400.00
Jacket Thickness, tj = 100.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength,  $f_{fu}$  = 1055.00
Tensile Modulus,  $E_f$  = 64828.00
Elongation,  $ef_u$  = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

Stepwise Properties
-----
EDGE -A-
Bending Moment,  $M_a$  = -1.6212E+007
Shear Force,  $V_a$  = -5348.301
EDGE -B-
Bending Moment,  $M_b$  = 163137.319
Shear Force,  $V_b$  = 5348.301
BOTH EDGES
Axial Force,  $F$  = -17151.026
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $As_t$  = 0.00
-Compression:  $As_c$  = 5353.274
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $As_{t,ten}$  = 1137.257
-Compression:  $As_{c,com}$  = 2208.54
-Middle:  $As_{mid}$  = 2007.478
Mean Diameter of Tension Reinforcement,  $Db_{L,ten}$  = 16.80
-----

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity  $V_R = \phi V_n = 943739.423$ 
 $V_n$  ((10.3), ASCE 41-17) =  $k_n l^* V_{CoIO} = 943739.423$ 

```

VCol = 943739.423  
 knl = 1.00  
 displacement\_ductility\_demand = 0.03533747

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:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 18.36364$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 163137.319$   
 $V_u = 5348.301$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 17151.026$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 796878.80$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 722566.31$   
 $V_{s,j1} = 251327.412$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,j2} = 471238.898$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 74312.489$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 420.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 74312.489$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 420.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 683214.917$   
 $b_w = 400.00$

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

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

From analysis, chord rotation  $\theta = 1.7467225E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.0004943$  ((4.29), Biskinis Phd))

$M_y = 7.0217E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4205E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.54545$

$N = 17151.026$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

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

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

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

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

$y_{ten} = 5.2949365E-006$

with  $f_y = 601.9953$

$d = 707.00$

$y = 0.19595022$

$A = 0.01014948$

$B = 0.00445989$

with  $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 17151.026$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.5451003E-005$

with  $f_c' (12.3, (ACI 440)) = 30.48734$

$f_c = 30.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e/A_c = 0.31291181$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 25742.96$

$y = 0.19514499$

$A = 0.01001989$

$B = 0.00440616$

with  $E_s = 200000.00$

CONFIRMATION:  $y = 0.19595022 < t/d$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

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

At local axis: 2

Integration Section: (b)

## Calculation No. 6

column C1, Floor 1

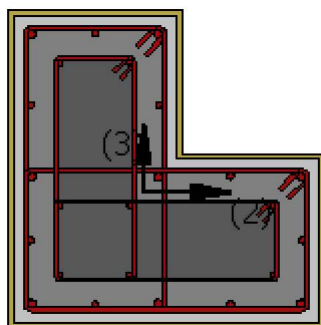
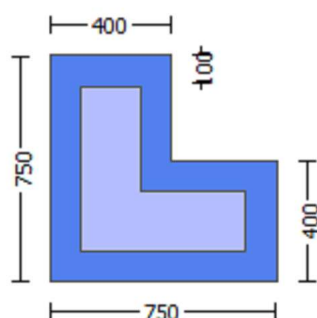
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: End

Local Axis: (2)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.27105  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 3  
 EDGE -A-  
 Shear Force,  $V_a = -0.000297$   
 EDGE -B-  
 Shear Force,  $V_b = 0.000297$   
 BOTH EDGES  
 Axial Force,  $F = -16273.615$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{sl,t} = 0.00$   
   -Compression:  $A_{sl,c} = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 1137.257$   
   -Compression:  $A_{sl,com} = 2208.54$   
   -Middle:  $A_{sl,mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.21726$   
 Member Controlled by Shear ( $V_e/V_r > 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$   
 with  
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 1.8183E+009$   
 $\mu_{u1+} = 1.5436E+009$ , 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  
 $\mu_{u1-} = 1.8183E+009$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 1.8183E+009$   
 $\mu_{u2+} = 1.5436E+009$ , 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  
 $\mu_{u2-} = 1.8183E+009$ , 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:

$$\mu = 5.2115571E-005$$

$$\mu_{1+} = 1.5436E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\alpha_{1+} (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_{1+}: \mu_{1+}^* = \text{shear\_factor} * \text{Max}(\mu_{1+}, \alpha_{1+}) = 0.01596533$$

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

$$\text{From (5.4b), TBDY: } \mu_{1+} = 0.01596533$$

$$\mu_{1+} \text{ (5.4c, TBDY)} = \alpha_{1+} * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$$

where  $f = \alpha_{1+} * \rho_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0465966$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$f_y = 0.0465966$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$\alpha_{se} \text{ ((5.4d), TBDY)} = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

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

$$\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

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

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} \cdot F_{ywe} = \min(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$

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

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

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

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

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

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$

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

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

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

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

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

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

$c$  = confinement factor = 1.27105

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 896.8923$

$fy1 = 747.4102$

$su1 = 0.032$

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

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

Shear\_factor = 1.00

$lo/lo_{min} = lb/l_d = 1.00$

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

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

For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered

characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

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

with  $fs1 = (fs_{jacket} \cdot A_{sl,ten,jacket} + fs_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 747.4102$

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

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 906.1344$

$fy2 = 755.112$

$su2 = 0.032$

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

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

Shear\_factor = 1.00

$lo/lo_{min} = lb/l_b, min = 1.00$

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

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

For calculation of  $esu2_{nominal}$  and  $y2, sh2, ft2, fy2$ , it is considered

characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

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

with  $fs2 = (fs_{jacket} \cdot A_{sl,com,jacket} + fs_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 755.112$

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

$yv = 0.0025$

$shv = 0.008$

$ftv = 902.993$

$fyv = 752.4941$

$suv = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lo_{u,min} = lb/ld = 1.00$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 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  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 752.4941$   
 with  $Esv = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.05343374$   
 $2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.10483702$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.09496245$

and confined core properties:

$b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.06065386$   
 $2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.11900291$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.10779406$

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

--->  
 $v < vs_{y2}$  - LHS eq.(4.5) is not satisfied

--->  
 $v < vs_c$  - RHS eq.(4.5) is satisfied

--->  
 $su (4.8) = 0.13151351$   
 $Mu = MRc (4.15) = 1.5436E+009$   
 $u = su (4.1) = 5.2115571E-005$

Calculation of ratio  $lb/ld$

Adequate Lap Length:  $lb/ld \geq 1$

Calculation of  $Mu1$ -

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

$u = 6.7707597E-005$   
 $Mu = 1.8183E+009$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00191815$   
 $N = 16273.615$   
 $fc = 30.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = shear\_factor * Max(cu, cc) = 0.01596533$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01596533$   
 $we ((5.4c), TBDY) = ase * sh_{min} * fy_{we} / fce + Min(fx, fy) = 0.09711526$   
 where  $f = af * pf * ffe / fce$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)  
 $fx = 0.0465966$



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

$af = 0.31984848$

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

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff,e = 860.3348$

$f_y = 0.0465966$

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

$af = 0.31984848$

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

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff,e = 860.3348$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.45746528$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

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

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

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

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

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

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.31295$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

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

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

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

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

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

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

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

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

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

```

Asec = 440000.00
s1 = 100.00
s2 = 250.00
fywe1 = 781.25
fywe2 = 656.25
fce = 30.00
From ((5.A.5), TBDY), TBDY: cc = 0.00471045
c = confinement factor = 1.27105
y1 = 0.0025
sh1 = 0.008
ft1 = 906.1344
fy1 = 755.112
su1 = 0.032
using (30) in Biskinis/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 = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 755.112
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 896.8923
fy2 = 747.4102
su2 = 0.032
using (30) in Biskinis/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 = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 747.4102
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105

```

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.2415059$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12309166$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.21875854$$

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

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

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

$$\mu_u(4.8) = 0.3315127$$

$$M_u = M_{Rc}(4.15) = 1.8183E+009$$

$$u = \mu_u(4.1) = 6.7707597E-005$$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

Calculation of  $M_{u2+}$

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

$$u = 5.2115571E-005$$

$$M_u = 1.5436E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \alpha_{co}) = 0.01596533$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.01596533$$

$$\mu_{we}((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_{x}, f_y) = 0.09711526$$

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

$$f_x = 0.0465966$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$f_y = 0.0465966$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u,f = 0.015$$

$$ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.45746528$$

$$ase1 = \text{Max}(((Aconf,max1 - AnoConf1)/Aconf,max1)*(Aconf,min1/Aconf,max1), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

Aconf,min1 = 293525.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

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

$$ase2 (>=ase1) = \text{Max}(((Aconf,max2 - AnoConf2)/Aconf,max2)*(Aconf,min2/Aconf,max2), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

$$psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.31295$$

$$psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$$

$$psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709$$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

$$psh2 (5.4d) = Lstir2*Astir2/(Asec*s2) = 0.00067082$$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

$$psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$$

$$psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709$$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

$$psh2 ((5.4d), TBDY) = Lstir2*Astir2/(Asec*s2) = 0.00067082$$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

$$Asec = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 781.25$$

$$fywe2 = 656.25$$

$$fce = 30.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00471045$$

$$c = \text{confinement factor} = 1.27105$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 896.8923$$

$$fy1 = 747.4102$$

$$su1 = 0.032$$

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

$$lo/lo,min = lb/l_d = 1.00$$

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

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

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

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

$$\text{with } fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 747.4102$$

```

with Es1 = (Esjacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 906.1344
fy2 = 755.112
su2 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 755.112
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
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 = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.13151351
Mu = MRc (4.15) = 1.5436E+009
u = su (4.1) = 5.2115571E-005

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

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

$$u = 6.7707597E-005$$

$$\mu = 1.8183E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00191815$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\phi_0 (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_0) = 0.01596533$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01596533$$

$$\phi_{we} ((5.4c), \text{TBDY}) = a_{se} * \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.09711526$$

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

$$\phi_{fx} = 0.0465966$$

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

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$\phi_{fy} = 0.0465966$$

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

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), \text{TBDY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

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

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

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

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.31295$

---

$psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ (5.4d)} = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

$psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

$Asec = 440000.00$   
 $s1 = 100.00$   
 $s2 = 250.00$   
 $fywe1 = 781.25$   
 $fywe2 = 656.25$   
 $fce = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$

$y1 = 0.0025$   
 $sh1 = 0.008$   
 $ft1 = 906.1344$   
 $fy1 = 755.112$   
 $su1 = 0.032$

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

$lo/lou,min = lb/ld = 1.00$

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

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

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

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

with  $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 755.112$

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

$y2 = 0.0025$   
 $sh2 = 0.008$   
 $ft2 = 896.8923$   
 $fy2 = 747.4102$   
 $su2 = 0.032$

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

$lo/lou,min = lb/lb,min = 1.00$

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

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

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

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

with  $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 747.4102$

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

$yv = 0.0025$   
 $shv = 0.008$   
 $ftv = 902.993$   
 $fyv = 752.4941$   
 $suv = 0.032$

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

and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 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  $Min(1,1.25*(l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs\_jacket*Asl_{mid,jacket} + fs_{mid}*Asl_{mid,core})/Asl_{mid} = 752.4941$   
 with  $Esv = (Es\_jacket*Asl_{mid,jacket} + Es_{mid}*Asl_{mid,core})/Asl_{mid} = 200000.00$   
 $1 = Asl_{ten}/(b*d)*(fs1/fc) = 0.1965694$   
 $2 = Asl_{com}/(b*d)*(fs2/fc) = 0.10018826$   
 $v = Asl_{mid}/(b*d)*(fsv/fc) = 0.1780546$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl_{ten}/(b*d)*(fs1/fc) = 0.2415059$   
 $2 = Asl_{com}/(b*d)*(fs2/fc) = 0.12309166$   
 $v = Asl_{mid}/(b*d)*(fsv/fc) = 0.21875854$

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

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $su (4.8) = 0.3315127$   
 $Mu = MRc (4.15) = 1.8183E+009$   
 $u = su (4.1) = 6.7707597E-005$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of Shear Strength  $V_r = Min(V_{r1}, V_{r2}) = 995834.294$

Calculation of Shear Strength at edge 1,  $V_{r1} = 995834.294$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $knl = 1$  (zero step-static loading)

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

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.54545$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $Mu = 30.3689$   
 $Vu = 0.000297$   
 $d = 0.8 * h = 600.00$   
 $Nu = 16273.615$   
 $Ag = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$   
 $V_{s,j1} = 589048.623$  is calculated for section web jacket, with:  
 $d = 600.00$



$A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314159.265$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 92890.612$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$   
 $df_v = d$  (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:  $V_s + V_f \leq 836763.965$   
 $bw = 400.00$

-----  
 Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$   
 $V_{r2} = V_{Col}((10.3), ASCE 41-17) = knl \cdot V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $knl = 1$  (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:  $f'_c = (f'_c_{jacket} \cdot \text{Area}_{jacket} + f'_c_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 30.36921$   
 $V_u = 0.000297$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$   
 $V_{s,j1} = 589048.623$  is calculated for section web jacket, with:

$d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314159.265$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 92890.612$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL * t / NoDir = 1.016$   
 $df_v = d$  (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:  $V_s + V_f \leq 836763.965$   
 $bw = 400.00$

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

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

Constant Properties

-----  
 Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$

```

Steel Elasticity, Es = 200000.00
Existing Column
Existing material of Primary Member: Concrete Strength, fc = fcm = 24.00
Existing material of Primary Member: Steel Strength, fs = fsm = 525.00
Concrete Elasticity, Ec = 23025.204
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 = 781.25
Existing Column
Existing material: Steel Strength, fs = 1.25*fsm = 656.25
#####
Max Height, Hmax = 750.00
Min Height, Hmin = 400.00
Max Width, Wmax = 750.00
Min Width, Wmin = 400.00
Jacket Thickness, tj = 100.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.27105
Element Length, L = 3000.00
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length (lo/lou,min>=1)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, ffu = 1055.00
Tensile Modulus, Ef = 64828.00
Elongation, efu = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

Stepwise Properties
-----
At local axis: 2
EDGE -A-
Shear Force, Va = -0.00029699
EDGE -B-
Shear Force, Vb = 0.00029699
BOTH EDGES
Axial Force, F = -16273.615
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 5353.274
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1137.257
-Compression: Asl,com = 2208.54
-Middle: Asl,mid = 2007.478
-----
-----

Calculation of Shear Capacity ratio , Ve/Vr = 1.21726
Member Controlled by Shear (Ve/Vr > 1)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 Ve = (Mpr1 + Mpr2)/ln = 1.2122E+006
with
Mpr1 = Max(Mu1+ , Mu1-) = 1.8183E+009
Mu1+ = 1.5436E+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

$Mu1- = 1.8183E+009$ , 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

$Mpr2 = \text{Max}(Mu2+, Mu2-) = 1.8183E+009$

$Mu2+ = 1.5436E+009$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu2- = 1.8183E+009$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $Mu1+$

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

$\phi_u = 5.2115571E-005$

$Mu = 1.5436E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00102302$

$N = 16273.615$

$f_c = 30.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01596533$

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

From (5.4b), TBDY:  $\phi_u = 0.01596533$

we ((5.4c), TBDY) =  $a_{se} * \phi_{u, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.09711526$

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

$\phi_x = 0.0465966$

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

$a_f = 0.31984848$

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

$b_{\max} = 750.00$

$h_{\max} = 750.00$

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

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$\phi_y = 0.0465966$

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

$a_f = 0.31984848$

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

$b_{\max} = 750.00$

$h_{\max} = 750.00$

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

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$R = 40.00$

Effective FRP thickness,  $t_f = NL * t * \cos(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$

$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

$A_{\text{conf,min1}} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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

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

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

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

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

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.31295$

-----  
 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

-----  
 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

$c = \text{confinement factor} = 1.27105$

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 896.8923$

$fy1 = 747.4102$

$su1 = 0.032$

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

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

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

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

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

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

with  $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 747.4102$

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

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 906.1344$

$fy2 = 755.112$

$su2 = 0.032$

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

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

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

From table 5A.1, TBDY:  $es_{u2\_nominal} = 0.08$ ,  
For calculation of  $es_{u2\_nominal}$  and  $y_2$ ,  $sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $fs_{y2} = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 755.112$   
with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0025$   
 $sh_v = 0.008$   
 $ft_v = 902.993$   
 $fy_v = 752.4941$   
 $s_{uv} = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 1.00$   
 $s_{uv} = 0.4 \cdot es_{uv\_nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $es_{uv\_nominal} = 0.08$ ,  
considering characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY  
For calculation of  $es_{uv\_nominal}$  and  $y_v$ ,  $sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 752.4941$   
with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.05343374$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.10483702$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.09496245$   
and confined core properties:  
 $b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.06065386$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.11900291$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.10779406$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)  
--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
--->  
 $su (4.8) = 0.13151351$   
 $Mu = MRc (4.15) = 1.5436E+009$   
 $u = su (4.1) = 5.2115571E-005$

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

Adequate Lap Length:  $lb/ld \geq 1$   
-----  
-----  
-----

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

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

$u = 6.7707597E-005$   
 $Mu = 1.8183E+009$   
-----

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00191815$

$N = 16273.615$   
 $f_c = 30.00$   
 $\alpha (5A.5, TBDY) = 0.002$   
 Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01596533$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\alpha = 0.01596533$   
 $\alpha_e ((5.4c), TBDY) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$   
 where  $f = \alpha * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0465966$   
 Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$   
 $\alpha_f = 0.31984848$   
 with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$   
 $b_{\max} = 750.00$   
 $h_{\max} = 750.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{f,e} = 860.3348$

$f_y = 0.0465966$   
 Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$   
 $\alpha_f = 0.31984848$   
 with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$   
 $b_{\max} = 750.00$   
 $h_{\max} = 750.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{f,e} = 860.3348$

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{f,f} = 0.015$

$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$   
 $\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$   
 The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{\text{conf,min1}} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.  
 $A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$   
 The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{\text{conf,max2}} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{\text{conf,min2}} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max2}}$  by a length equal to half the clear spacing between internal hoops.  
 $A_{\text{noConf2}} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $p_{sh,\min} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 3.31295$

$p_{sh,x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{s2} * f_{ywe2} = 3.31295$   
 $p_{sh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2} ((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 3.31295  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00367709  
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00067082  
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A.5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 906.1344

fy1 = 755.112

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 755.112

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

y2 = 0.0025

sh2 = 0.008

ft2 = 896.8923

fy2 = 747.4102

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 747.4102

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

yv = 0.0025

shv = 0.008

ftv = 902.993

fyv = 752.4941

suv = 0.032

using (30) in Biskinis/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 = 1.00

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 = 752.4941

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



$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1965694$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.10018826$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1780546$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 38.13135$$

$$cc (5A.5, TBDY) = 0.00471045$$

$$c = \text{confinement factor} = 1.27105$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.2415059$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12309166$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.21875854$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

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

--->

$$s_u (4.8) = 0.3315127$$

$$\mu_u = M_{Rc} (4.15) = 1.8183E+009$$

$$u = s_u (4.1) = 6.7707597E-005$$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of  $\mu_{u2+}$

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

$$u = 5.2115571E-005$$

$$\mu_u = 1.5436E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, cc) = 0.01596533$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.01596533$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$$

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

$$f_x = 0.0465966$$

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

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$f_y = 0.0465966$$

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

$$a_f = 0.31984848$$

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

bmax = 750.00  
hmax = 750.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$   
bw = 400.00  
effective stress from (A.35),  $ff,e = 860.3348$

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

$ase((5.4d), TBDY) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.45746528$

$ase1 = Max(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

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

$ase2 (>= ase1) = Max(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

$psh_{,min} * F_{ywe} = Min(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 3.31295$

$psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

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

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

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

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

$psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

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

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

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

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

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

$c$  = confinement factor = 1.27105

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 896.8923$

$fy1 = 747.4102$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,  
 For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = (fs_{jacket} * A_{s,ten,jacket} + fs_{core} * A_{s,ten,core}) / A_{s,ten} = 747.4102$   
 with  $Es_1 = (Es_{jacket} * A_{s,ten,jacket} + Es_{core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$   
 $y_2 = 0.0025$   
 $sh_2 = 0.008$   
 $ft_2 = 906.1344$   
 $fy_2 = 755.112$   
 $su_2 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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.  
 $y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * A_{s,com,jacket} + fs_{core} * A_{s,com,core}) / A_{s,com} = 755.112$   
 with  $Es_2 = (Es_{jacket} * A_{s,com,jacket} + Es_{core} * A_{s,com,core}) / A_{s,com} = 200000.00$   
 $y_v = 0.0025$   
 $sh_v = 0.008$   
 $ft_v = 902.993$   
 $fy_v = 752.4941$   
 $suv = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * A_{s,mid,jacket} + fs_{mid} * A_{s,mid,core}) / A_{s,mid} = 752.4941$   
 with  $Es_v = (Es_{jacket} * A_{s,mid,jacket} + Es_{mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b * d) * (fs_1 / fc) = 0.05343374$   
 $2 = A_{s,com} / (b * d) * (fs_2 / fc) = 0.10483702$   
 $v = A_{s,mid} / (b * d) * (fsv / fc) = 0.09496245$   
 and confined core properties:  
 $b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = A_{s,ten} / (b * d) * (fs_1 / fc) = 0.06065386$   
 $2 = A_{s,com} / (b * d) * (fs_2 / fc) = 0.11900291$   
 $v = A_{s,mid} / (b * d) * (fsv / fc) = 0.10779406$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $su (4.8) = 0.13151351$   
 $Mu = MRc (4.15) = 1.5436E+009$   
 $u = su (4.1) = 5.2115571E-005$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of  $\mu_2$

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

$$\mu = 6.7707597E-005$$

$$\mu_2 = 1.8183E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00191815$$

$$N = 16273.615$$

$$f_c = 30.00$$

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

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear\_factor} * \text{Max}(\mu_2, \alpha_0) = 0.01596533$$

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

$$\text{From (5.4b), TBDY: } \mu_2 = 0.01596533$$

$$\text{we ((5.4c), TBDY) } = \alpha_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$$

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

$$f_x = 0.0465966$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$f_y = 0.0465966$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$\alpha_{se} \text{ ((5.4d), TBDY)} = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-AnoConf2)/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$   
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.  
AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min * Fywe = \text{Min}(psh,x * Fywe, psh,y * Fywe) = 3.31295$

$psh,x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
 $psh1 ((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d)) = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

$psh,y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
 $psh1 ((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 906.1344

fy1 = 755.112

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket \* Asl,ten,jacket + fs,core \* Asl,ten,core) / Asl,ten = 755.112

with Es1 = (Es,jacket \* Asl,ten,jacket + Es,core \* Asl,ten,core) / Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 896.8923

fy2 = 747.4102

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{s2} = (f_{sjacket} \cdot A_{sl,com,jacket} + f_{s,core} \cdot A_{sl,com,core})/A_{sl,com} = 747.4102$   
 with  $E_{s2} = (E_{sjacket} \cdot A_{sl,com,jacket} + E_{s,core} \cdot A_{sl,com,core})/A_{sl,com} = 200000.00$   
 $y_v = 0.0025$   
 $sh_v = 0.008$   
 $ft_v = 902.993$   
 $f_{y_v} = 752.4941$   
 $s_{uv} = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $s_{uv} = 0.4 \cdot e_{suv,nominal} ((5.5), \text{TBDY}) = 0.032$   
 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  $y_v, sh_v, ft_v, f_{y_v}$ , it is considered  
 characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{sv} = (f_{sjacket} \cdot A_{sl,mid,jacket} + f_{s,mid} \cdot A_{sl,mid,core})/A_{sl,mid} = 752.4941$   
 with  $E_{sv} = (E_{sjacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core})/A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1965694$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.10018826$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.1780546$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, \text{TBDY}) = 38.13135$   
 $cc (5A.5, \text{TBDY}) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.2415059$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12309166$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.21875854$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$  - RHS eq.(4.5) is satisfied

--->

$s_u (4.8) = 0.3315127$

$\mu_u = M_{Rc} (4.15) = 1.8183E+009$

$u = s_u (4.1) = 6.7707597E-005$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 995834.294$

Calculation of Shear Strength at edge 1,  $V_{r1} = 995834.294$

$V_{r1} = V_{Col} ((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{Col0}$

$V_{Col0} = 995834.294$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d/s$ ' is replaced by ' $V_{s+} = f \cdot V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core})/\text{Area}_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu = 30.38488$   
 $V_u = 0.00029699$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$   
 $V_{s,j1} = 314159.265$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,j2} = 589048.623$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 92890.612$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (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:  $V_s + V_f \leq 836763.965$   
 $b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $k_{nl} = 1$  (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).

$\gamma = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.54545$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$   
 $\mu_u = 30.38458$   
 $V_u = 0.00029699$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 903207.888$   
 $V_{sj1} = 314159.265$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.3125$   
 $V_{sj2} = 589048.623$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 92890.612$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $b_w = 400.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At local axis: 2  
 -----

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjcs



## 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 Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_b/l_d \geq 1$ )

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

Bending Moment,  $M = -60775.497$

Shear Force,  $V_2 = 5348.301$

Shear Force,  $V_3 = -78.97309$

Axial Force,  $F = -17151.026$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1137.257$

-Compression:  $As_{l,com} = 2208.54$

-Middle:  $As_{l,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten,jacket} = 829.3805$

-Compression:  $As_{l,com,jacket} = 1746.726$

-Middle:  $As_{l,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten,core} = 307.8761$

-Compression:  $As_{l,com,core} = 461.8141$

-Middle:  $As_{l,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $\phi_R = \phi_u = 0.0033335$

$$\phi_u = \phi_y + \phi_p = 0.0033335$$

- Calculation of  $\phi_y$  -

$$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00126799 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 7.0217E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 769.5722$$

$$\text{From table 10.5, ASCE 41_17: } E_{eff} = \text{factor} * E_c * I_g = 1.4205E+014$$

$$\text{factor} = 0.30$$

$$A_g = 440000.00$$

$$\text{Mean concrete strength: } f'_c = (f'_{c\_jacket} * A_{jacket} + f'_{c\_core} * A_{core}) / A_{section} = 27.54545$$

$$N = 17151.026$$

$$E_c * I_g = E_{c\_jacket} * I_{g\_jacket} + E_{c\_core} * I_{g\_core} = 4.7351E+014$$

Calculation of Yielding Moment  $M_y$

Calculation of  $\phi_y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $\phi_y < t/d$ , compression zone rectangular) with:

$$\text{flange width, } b = 750.00$$

$$\text{web width, } b_w = 400.00$$

$$\text{flange thickness, } t = 400.00$$

$$\phi_y = \text{Min}(\phi_{y\_ten}, \phi_{y\_com})$$

$$\phi_{y\_ten} = 5.2949365E-006$$

$$\text{with } f_y = 601.9953$$

$$d = 707.00$$

$$\phi_y = 0.19595022$$

$$A = 0.01014948$$

$$B = 0.00445989$$

$$\text{with } p_t = 0.0064556$$

$$p_c = 0.00416509$$

$$p_v = 0.00378591$$

$$N = 17151.026$$

$$b = 750.00$$

$$\phi_y = 0.06082037$$

$$\phi_{y\_comp} = 1.5451003E-005$$

$$\text{with } f'_c * (12.3, (ACI 440)) = 30.48734$$

$$f_c = 30.00$$

$$f_l = 0.49678681$$

$$b = b_{max} = 750.00$$

$$h = h_{max} = 750.00$$

$$A_g = 0.44$$

$$g = p_t + p_c + p_v = 0.01009575$$

$$r_c = 40.00$$

$$A_e / A_c = 0.31291181$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$\text{effective strain from (12.5) and (12.12), } \epsilon_{fe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 25742.96$$

$$\phi_y = 0.19514499$$

$$A = 0.01001989$$

$$B = 0.00440616$$

$$\text{with } E_s = 200000.00$$

CONFIRMATION:  $\phi_y = 0.19595022 < t/d$

Calculation of ratio  $I_b / I_d$

Adequate Lap Length:  $I_b / I_d \geq 1$

- Calculation of  $p$  -

From table 10-8:  $p = 0.00206551$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/l_d \geq 1$

shear control ratio  $V_yE/V_{ColOE} = 1.21726$

$d = d_{\text{external}} = 707.00$

$s = s_{\text{external}} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f/bw \cdot (f_{fe}/f_s) = 0.0064556$

jacket:  $s_1 = A_{v1} \cdot L_{\text{stir1}}/(s_1 \cdot A_g) = 0.00367709$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{\text{stir1}} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot L_{\text{stir2}}/(s_2 \cdot A_g) = 0.00067082$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{\text{stir2}} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2 \cdot t_f/bw \cdot (f_{fe}/f_s)$  is implemented to account for FRP contribution

where  $f = 2 \cdot t_f/bw$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe}/f_s$  normalises  $f$  to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 17151.026$

$A_g = 440000.00$

$f_{cE} = (f_{c,jacket} \cdot A_{\text{jacket}} + f_{c,core} \cdot A_{\text{core}})/\text{section\_area} = 27.54545$

$f_{yE} = (f_{y,ext\_Long\_Reinf} \cdot A_{\text{ext\_Long\_Reinf}} + f_{y,int\_Long\_Reinf} \cdot A_{\text{int\_Long\_Reinf}})/A_{\text{Tot\_Long\_Rein}} = 601.9953$

$f_{yE} = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2)/(s_1 + s_2) = 609.5715$

$p_l = A_{\text{Tot\_Long\_Rein}}/(b \cdot d) = 0.01009575$

$b = 750.00$

$d = 707.00$

$f_{cE} = 27.54545$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 7

column C1, Floor 1

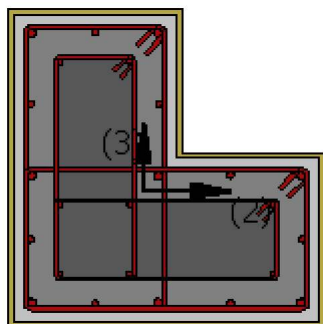
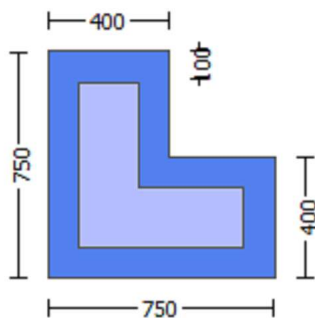
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjlcs

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 Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_c = f_{cm} = 30.00$

New material: Steel Strength,  $f_s = f_{sm} = 625.00$

Existing Column

Existing material: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )

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°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

#### Stepwise Properties

EDGE -A-  
Bending Moment, Ma = -174480.279  
Shear Force, Va = 78.97309  
EDGE -B-  
Bending Moment, Mb = -60775.497  
Shear Force, Vb = -78.97309  
BOTH EDGES  
Axial Force, F = -17151.026  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 5353.274  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 1137.257  
-Compression: Asl,com = 2208.54  
-Middle: Asl,mid = 2007.478  
Mean Diameter of Tension Reinforcement, DbL,ten = 16.80

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity VR = \*Vn = 943739.423  
Vn ((10.3), ASCE 41-17) = knl\*VColO = 943739.423  
VCol = 943739.423  
knl = 1.00  
displacement\_ductility\_demand = 1.3170134E-005

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 = 18.36364, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)  
M/Vd = 2.00  
Mu = 60775.497  
Vu = 78.97309  
d = 0.8\*h = 600.00  
Nu = 17151.026  
Ag = 300000.00  
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 796878.80  
where:  
Vs,jacket = Vs,j1 + Vs,j2 = 722566.31  
Vs,j1 = 471238.898 is calculated for section web jacket, with:  
d = 600.00  
Av = 157079.633  
fy = 500.00  
s = 100.00  
Vs,j1 is multiplied by Col,j1 = 1.00  
s/d = 0.16666667  
Vs,j2 = 251327.412 is calculated for section flange jacket, with:  
d = 320.00  
Av = 157079.633  
fy = 500.00  
s = 100.00  
Vs,j2 is multiplied by Col,j2 = 1.00  
s/d = 0.3125  
Vs,core = Vs,c1 + Vs,c2 = 74312.489  
Vs,c1 = 74312.489 is calculated for section web core, with:  
d = 440.00  
Av = 100530.965

$f_y = 420.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 420.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 $\ln(11.3) \sin + \cos$  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,  $tf1 = NL \cdot t / \text{NoDir} = 1.016$   
 $dfv = d$  (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:  $V_s + V_f \leq 683214.917$   
 $bw = 400.00$

displacement ductility demand is calculated as  $\delta / y$

- Calculation of  $\delta / y$  for END B -  
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation  $\theta = 1.6699628E-008$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00126799$  ((4.29), Biskinis Phd))  
 $M_y = 7.0217E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 769.5722  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.4205E+014$   
 $\text{factor} = 0.30$   
 $A_g = 440000.00$   
 Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.54545$   
 $N = 17151.026$   
 $E_c \cdot I_g = E_{c,\text{jacket}} \cdot I_{g,\text{jacket}} + E_{c,\text{core}} \cdot I_{g,\text{core}} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$   
 web width,  $bw = 400.00$   
 flange thickness,  $t = 400.00$

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 5.2949365E-006$   
 with  $f_y = 601.9953$   
 $d = 707.00$   
 $y = 0.19595022$   
 $A = 0.01014948$   
 $B = 0.00445989$   
 with  $pt = 0.00214476$   
 $pc = 0.00416509$

$p_v = 0.00378591$   
 $N = 17151.026$   
 $b = 750.00$   
 $" = 0.06082037$   
 $y_{comp} = 1.5451003E-005$   
 with  $f_c^* (12.3, (ACI 440)) = 30.48734$   
 $f_c = 30.00$   
 $f_l = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $rc = 40.00$   
 $A_e/A_c = 0.31291181$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 25742.96$   
 $y = 0.19514499$   
 $A = 0.01001989$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.19595022 < t/d$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 8

column C1, Floor 1

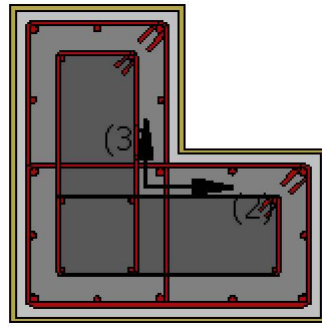
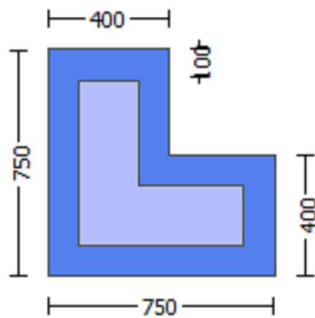
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.27105

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $ef_u = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $bi: 0.00^\circ$

Number of layers,  $NL = 1$



Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -0.000297$

EDGE -B-

Shear Force,  $V_b = 0.000297$

BOTH EDGES

Axial Force,  $F = -16273.615$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1137.257$

-Compression:  $As_{c,com} = 2208.54$

-Middle:  $As_{mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.21726$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$  with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.8183E+009$

$\mu_{1+} = 1.5436E+009$ , 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

$\mu_{1-} = 1.8183E+009$ , 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.8183E+009$

$\mu_{2+} = 1.5436E+009$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 1.8183E+009$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $\mu_{1+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 5.2115571E-005$

$M_u = 1.5436E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00102302$

$N = 16273.615$

$f_c = 30.00$

$\phi$  (5A.5, TBDY) = 0.002

Final value of  $\phi \mu$ :  $\phi \mu^* = \text{shear\_factor} * \text{Max}(\phi \mu, \phi c) = 0.01596533$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi \mu = 0.01596533$

we ((5.4c), TBDY) =  $a_s e^* \text{sh}_{\min} f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$

where  $f = a_f^* p_f^* f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00508$   
 $bw = 400.00$   
effective stress from (A.35),  $ff,e = 860.3348$

$f_y = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff,e = 860.3348$

$R = 40.00$

Effective FRP thickness,  $tf = NL \cdot t \cdot \cos(b1) = 1.016$

$f_u, f = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$

$ase ((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int})/A_{sec} = 0.45746528$

$ase1 = \text{Max}(((A_{conf, \max 1} - A_{noConf1})/A_{conf, \max 1}) \cdot (A_{conf, \min 1}/A_{conf, \max 1}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf, \min 1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf, \max 1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf, \max 2} - A_{noConf2})/A_{conf, \max 2}) \cdot (A_{conf, \min 2}/A_{conf, \max 2}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf, \min 2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf, \max 2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{\min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d)) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

```

fce = 30.00
From ((5.A5), TBDY), TBDY: cc = 0.00471045
c = confinement factor = 1.27105
y1 = 0.0025
sh1 = 0.008
ft1 = 896.8923
fy1 = 747.4102
su1 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 747.4102
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 906.1344
fy2 = 755.112
su2 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 755.112
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
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 = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

```

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $\mu_u(4.8) = 0.13151351$   
 $M_u = M_{Rc}(4.15) = 1.5436E+009$   
 $u = \mu_u(4.1) = 5.2115571E-005$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

Calculation of  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu_u = 6.7707597E-005$   
 $M_u = 1.8183E+009$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00191815$   
 $N = 16273.615$

$f_c = 30.00$   
 $\alpha_{co}(5A.5, TBDY) = 0.002$

Final value of  $\mu_{cu}$ :  $\mu_{cu}^* = \text{shear\_factor} * \text{Max}(\mu_{cu}, \alpha_{co}) = 0.01596533$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_{cu} = 0.01596533$

$\mu_{we}((5.4c), TBDY) = \alpha_{se} * \text{sh\_min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$

where  $f = \alpha_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$f_y = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$R = 40.00$

Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

$\alpha_{se}((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.31295$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

$c$  = confinement factor = 1.27105

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 906.1344$

$fy1 = 755.112$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 755.112$

with  $Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 896.8923$

$fy2 = 747.4102$

```

su2 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 747.4102
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
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 = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 5.2115571E-005

Mu = 1.5436E+009

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\alpha (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \alpha = 0.01596533$$

$$\alpha_e ((5.4c), \text{TB DY}) = \alpha_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$$

where  $f = \alpha^* p f^* f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0465966$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p f = 2 t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$f_y = 0.0465966$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p f = 2 t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_u, f = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$\alpha_e ((5.4d), \text{TB DY}) = (\alpha_e 1 * A_{\text{ext}} + \alpha_e 2 * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\alpha_e 1 = \text{Max}(((A_{\text{conf}, \max 1} - A_{\text{noConf1}}) / A_{\text{conf}, \max 1}) * (A_{\text{conf}, \min 1} / A_{\text{conf}, \max 1}), 0) = 0.45746528$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf}, \min}$  and  $A_{\text{conf}, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf}, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf}, \min 1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{\text{conf}, \max 1}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_e 2 (> \alpha_e 1) = \text{Max}(((A_{\text{conf}, \max 2} - A_{\text{noConf2}}) / A_{\text{conf}, \max 2}) * (A_{\text{conf}, \min 2} / A_{\text{conf}, \max 2}), 0) = 0.45746528$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf}, \min}$  and  $A_{\text{conf}, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf}, \max 2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{\text{conf}, \min 2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{\text{conf}, \max 2}$  by a length equal to half the clear spacing between internal hoops.

$A_{\text{noConf2}} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh, \min} * f_{ywe} = \text{Min}(p_{sh, x} * f_{ywe}, p_{sh, y} * f_{ywe}) = 3.31295$$

$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

$Asec = 440000.00$   
 $s1 = 100.00$   
 $s2 = 250.00$   
 $fywe1 = 781.25$   
 $fywe2 = 656.25$   
 $fce = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$

$y1 = 0.0025$   
 $sh1 = 0.008$   
 $ft1 = 896.8923$   
 $fy1 = 747.4102$   
 $su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou,min = lb/ld = 1.00$

$su1 = 0.4 * esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 747.4102$

with  $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$

$y2 = 0.0025$   
 $sh2 = 0.008$   
 $ft2 = 906.1344$   
 $fy2 = 755.112$   
 $su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$

$lo/lou,min = lb/lb,min = 1.00$

$su2 = 0.4 * esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$

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.

$y2, sh2, ft2, fy2$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 755.112$

with  $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$

$yv = 0.0025$   
 $shv = 0.008$   
 $ftv = 902.993$   
 $fyv = 752.4941$   
 $suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$

$lo/lou,min = lb/ld = 1.00$

$suv = 0.4 * esuv\_nominal \text{ ((5.5), TBDY)} = 0.032$

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  $e_{suv\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered  
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{sl,mid,jacket} + f_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 752.4941$

with  $E_{sv} = (E_{s,jacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$

$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1}/f_c) = 0.05343374$

$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2}/f_c) = 0.10483702$

$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv}/f_c) = 0.09496245$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 38.13135

$cc$  (5A.5, TBDY) = 0.00471045

$c$  = confinement factor = 1.27105

$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1}/f_c) = 0.06065386$

$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2}/f_c) = 0.11900291$

$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv}/f_c) = 0.10779406$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

---->

$v < v_{s,c}$  - RHS eq.(4.5) is satisfied

---->

$su$  (4.8) = 0.13151351

$Mu = MR_c$  (4.15) = 1.5436E+009

$u = su$  (4.1) = 5.2115571E-005

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of  $Mu_2$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 6.7707597E-005$

$Mu = 1.8183E+009$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00191815$

$N = 16273.615$

$f_c = 30.00$

$co$  (5A.5, TBDY) = 0.002

Final value of  $cu$ :  $cu^* = \text{shear\_factor} \cdot \text{Max}(cu, cc) = 0.01596533$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $cu = 0.01596533$

$w_e$  ((5.4c), TBDY) =  $ase \cdot sh_{min} \cdot fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.09711526$

where  $f = af \cdot pf \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$fx = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $f_{f,e} = 860.3348$

$f_y = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{f,e} = 860.3348$

$R = 40.00$

Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_u, f = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$

$a_{se} ((5.4d), TBDY) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int})/A_{sec} = 0.45746528$

$a_{se1} = \text{Max}(((A_{conf, \max 1} - A_{noConf1})/A_{conf, \max 1}) \cdot (A_{conf, \min 1}/A_{conf, \max 1}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf, \min 1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf, \max 1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf, \max 2} - A_{noConf2})/A_{conf, \max 2}) \cdot (A_{conf, \min 2}/A_{conf, \max 2}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf, \min 2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf, \max 2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh, \min} \cdot F_{ywe} = \text{Min}(p_{sh, x} \cdot F_{ywe}, p_{sh, y} \cdot F_{ywe}) = 3.31295$

$p_{sh, x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 3.31295$

$p_{sh1} ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2} ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh, y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 3.31295$

$p_{sh1} ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2} ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

```

c = confinement factor = 1.27105
y1 = 0.0025
sh1 = 0.008
ft1 = 906.1344
fy1 = 755.112
su1 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 755.112
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 896.8923
fy2 = 747.4102
su2 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 747.4102
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
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 = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied

```

```

--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005
-----

Calculation of ratio lb/ld
-----

Adequate Lap Length: lb/ld >= 1
-----
-----
-----

Calculation of Shear Strength Vr = Min(Vr1, Vr2) = 995834.294
-----

Calculation of Shear Strength at edge 1, Vr1 = 995834.294
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 995834.294
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*Areajacket + fc'core*Areacore)/Areasection = 27.54545, but fc'0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 30.3689
Vu = 0.000297
d = 0.8*h = 600.00
Nu = 16273.615
Ag = 300000.00
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 996098.499
where:
Vs,jacket = Vs,j1 + Vs,j2 = 903207.888
Vs,j1 = 589048.623 is calculated for section web jacket, with:
d = 600.00
Av = 157079.633
fy = 625.00
s = 100.00
Vs,j1 is multiplied by Colj1 = 1.00
s/d = 0.16666667
Vs,j2 = 314159.265 is calculated for section flange jacket, with:
d = 320.00
Av = 157079.633
fy = 625.00
s = 100.00
Vs,j2 is multiplied by Colj2 = 1.00
s/d = 0.3125
Vs,core = Vs,c1 + Vs,c2 = 92890.612
Vs,c1 = 92890.612 is calculated for section web core, with:
d = 440.00
Av = 100530.965
fy = 525.00
s = 250.00
Vs,c1 is multiplied by Colc1 = 1.00
s/d = 0.56818182
Vs,c2 = 0.00 is calculated for section flange core, with:
d = 160.00
Av = 100530.965
fy = 525.00
s = 250.00
Vs,c2 is multiplied by Colc2 = 0.00
s/d = 1.5625
Vf ((11-3)-(11.4), ACI 440) = 372533.843

```

$f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$   
 $V_{r2} = V_{Col}((10.3), \text{ASCE 41-17}) = knl \cdot V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $knl = 1$  (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).

$f = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot \text{Area}_{jacket} + f'_{c\_core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 30.36921$   
 $\nu_u = 0.000297$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$   
 $V_{s,j1} = 589048.623$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314159.265$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 92890.612$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$

$V_f((11-3)-(11.4), \text{ACI 440}) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjlc

#### Constant Properties

Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
 Concrete Elasticity,  $E_c = 23025.204$   
 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,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.27105  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou, min} \geq 1$ )

#### FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $N_{oDir} = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -0.00029699$

EDGE -B-

Shear Force,  $V_b = 0.00029699$

BOTH EDGES

Axial Force,  $F = -16273.615$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1137.257$

-Compression:  $As_{l,com} = 2208.54$

-Middle:  $As_{l,mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.21726$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$  with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.8183E+009$

$\mu_{u1+} = 1.5436E+009$ , 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

$\mu_{u1-} = 1.8183E+009$ , 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

$M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.8183E+009$

$\mu_{u2+} = 1.5436E+009$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u2-} = 1.8183E+009$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $\mu_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 5.2115571E-005$

$\mu_u = 1.5436E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00102302$

$N = 16273.615$

$f_c = 30.00$

$\phi_{co} (5A.5, TBDY) = 0.002$

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01596533$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.01596533$   
 $w_e ((5.4c), TBDY) = a_{se} \cdot s_{h,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$   
 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)

---


$$f_x = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$$b_w = 400.00$$

effective stress from (A.35),  $f_{fe} = 860.3348$

---


$$f_y = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

From EC8 A4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$$b_w = 400.00$$

effective stress from (A.35),  $f_{fe} = 860.3348$

---


$$R = 40.00$$

Effective FRP thickness,  $t_f = N_L \cdot t \cdot \cos(b_1) = 1.016$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$a_{se} ((5.4d), TBDY) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int})/A_{sec} = 0.45746528$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) \cdot (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) \cdot (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} \cdot f_{ywe} = \text{Min}(p_{sh,x} \cdot f_{ywe}, p_{sh,y} \cdot f_{ywe}) = 3.31295$$

---


$$p_{sh,x} \cdot f_{ywe} = p_{sh1} \cdot f_{ywe1} + p_{sh2} \cdot f_{ywe2} = 3.31295$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$$

$$L_{stir1} (\text{Length of stirrups along } Y) = 2060.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} (5.4d) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$$

$$L_{stir2} (\text{Length of stirrups along } Y) = 1468.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

---


$$p_{sh,y} \cdot f_{ywe} = p_{sh1} \cdot f_{ywe1} + p_{sh2} \cdot f_{ywe2} = 3.31295$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$$

$$L_{stir1} (\text{Length of stirrups along } X) = 2060.00$$



Astir1 (stirrups area) = 78.53982  
 psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00067082  
 Lstir2 (Length of stirrups along X) = 1468.00  
 Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 896.8923

fy1 = 747.4102

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 747.4102

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 906.1344

fy2 = 755.112

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 755.112

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025

shv = 0.008

ftv = 902.993

fyv = 752.4941

suv = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 752.4941

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.05343374

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.10483702

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.09496245

and confined core properties:

b = 690.00

$d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.06065386$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11900291$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.10779406$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->

$s_u (4.8) = 0.13151351$   
 $M_u = M_{Rc} (4.15) = 1.5436E+009$   
 $u = s_u (4.1) = 5.2115571E-005$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of  $M_{u1}$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 6.7707597E-005$   
 $M_u = 1.8183E+009$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00191815$   
 $N = 16273.615$   
 $f_c = 30.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01596533$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01596533$   
 $w_e ((5.4c), TBDY) = a_{se} * sh_{min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$   
 where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0465966$   
 Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$   
 $a_f = 0.31984848$   
 with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$   
 $b_{max} = 750.00$   
 $h_{max} = 750.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{fe} = 860.3348$

$f_y = 0.0465966$   
 Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$   
 $a_f = 0.31984848$   
 with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$   
 $b_{max} = 750.00$   
 $h_{max} = 750.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{fe} = 860.3348$

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_f = 0.015$   
 $ase((5.4d), TBDY) = (ase_1 \cdot A_{ext} + ase_2 \cdot A_{int}) / A_{sec} = 0.45746528$   
 $ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$

$psh_x \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 3.31295$   
 $psh_1((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh_2(5.4d) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 3.31295$   
 $psh_1((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh_2((5.4d), TBDY) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$   
 $s_1 = 100.00$   
 $s_2 = 250.00$   
 $f_{ywe1} = 781.25$   
 $f_{ywe2} = 656.25$   
 $f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$   
 $c$  = confinement factor = 1.27105

$y_1 = 0.0025$   
 $sh_1 = 0.008$   
 $ft_1 = 906.1344$   
 $fy_1 = 755.112$   
 $su_1 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/d = 1.00$   
 $su_1 = 0.4 \cdot esu_1_{nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = (fs\_jacket \cdot Asl\_ten\_jacket + fs\_core \cdot Asl\_ten\_core) / Asl\_ten = 755.112$   
with  $Es1 = (Es\_jacket \cdot Asl\_ten\_jacket + Es\_core \cdot Asl\_ten\_core) / Asl\_ten = 200000.00$   
 $y2 = 0.0025$   
 $sh2 = 0.008$   
 $ft2 = 896.8923$   
 $fy2 = 747.4102$   
 $su2 = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/lb, min = 1.00$   
 $su2 = 0.4 \cdot esu2\_nominal \cdot ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs2 = (fs\_jacket \cdot Asl\_com\_jacket + fs\_core \cdot Asl\_com\_core) / Asl\_com = 747.4102$   
with  $Es2 = (Es\_jacket \cdot Asl\_com\_jacket + Es\_core \cdot Asl\_com\_core) / Asl\_com = 200000.00$   
 $yv = 0.0025$   
 $shv = 0.008$   
 $ftv = 902.993$   
 $fyv = 752.4941$   
 $suv = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/ld = 1.00$   
 $suv = 0.4 \cdot esuv\_nominal \cdot ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs\_jacket \cdot Asl\_mid\_jacket + fs\_mid \cdot Asl\_mid\_core) / Asl\_mid = 752.4941$   
with  $Es_v = (Es\_jacket \cdot Asl\_mid\_jacket + Es\_mid \cdot Asl\_mid\_core) / Asl\_mid = 200000.00$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.1965694$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.10018826$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.1780546$   
and confined core properties:  
 $b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.2415059$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.12309166$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.21875854$   
Case/Assumption: Unconfined full section - Steel rupture  
'satisfies Eq. (4.3)  
--->  
 $v < vs, y2$  - LHS eq.(4.5) is not satisfied  
--->  
 $v < vs, c$  - RHS eq.(4.5) is satisfied  
--->  
 $su (4.8) = 0.3315127$   
 $Mu = MRc (4.15) = 1.8183E+009$   
 $u = su (4.1) = 6.7707597E-005$

Calculation of ratio  $lb/ld$

Adequate Lap Length:  $lb/ld \geq 1$

## Calculation of $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 5.2115571\text{E-}005$$

$$\mu_{\mu} = 1.5436\text{E+}009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\alpha_{\text{co}} (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_{\text{cu}}: \mu_{\text{cu}}^* = \text{shear\_factor} * \text{Max}(\mu_{\text{cu}}, \alpha_{\text{co}}) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{\text{cu}} = 0.01596533$$

$$\mu_{\text{we}} ((5.4c), \text{TBDY}) = \alpha_{\text{se}} * \mu_{\text{sh,min}} * f_{y\text{we}} / f_{\text{ce}} + \text{Min}(\mu_{\text{fx}}, \mu_{\text{fy}}) = 0.09711526$$

where  $\mu_{\text{f}} = \alpha_{\text{f}} * \mu_{\text{p}} * f_{\text{fe}} / f_{\text{ce}}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{\text{fx}} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_{\text{f}} = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_{\text{f}} = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{\text{pf}} = 2t_{\text{f}} / b_{\text{w}} = 0.00508$$

$$b_{\text{w}} = 400.00$$

$$\text{effective stress from (A.35), } f_{\text{fe}} = 860.3348$$

$$\mu_{\text{fy}} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_{\text{f}} = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_{\text{f}} = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{\text{pf}} = 2t_{\text{f}} / b_{\text{w}} = 0.00508$$

$$b_{\text{w}} = 400.00$$

$$\text{effective stress from (A.35), } f_{\text{fe}} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_{\text{f}} = N L^* t \cos(b_1) = 1.016$$

$$f_{\text{u,f}} = 1055.00$$

$$E_{\text{f}} = 64828.00$$

$$\mu_{\text{u,f}} = 0.015$$

$$\alpha_{\text{se}} ((5.4d), \text{TBDY}) = (\alpha_{\text{se1}} * A_{\text{ext}} + \alpha_{\text{se2}} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\alpha_{\text{se1}} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{\text{se2}} (>= \alpha_{\text{se1}}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.31295$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

$c$  = confinement factor = 1.27105

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 896.8923$

$fy1 = 747.4102$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{min} = lb/ld = 1.00$

$su1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$

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  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 747.4102$

with  $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 906.1344$

$fy2 = 755.112$

$su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{min} = lb/lb_{min} = 1.00$

$su2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$

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  $fs2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 755.112$

with  $Es2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$

$yv = 0.0025$

```

shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
    using (30) in Biskinis/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 = 1.00
    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 = 752.4941
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
    2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
    v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
    c = confinement factor = 1.27105
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
    2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
    v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.13151351
Mu = MRc (4.15) = 1.5436E+009
u = su (4.1) = 5.2115571E-005

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

```

u = 6.7707597E-005
Mu = 1.8183E+009

```

with full section properties:

```

b = 400.00
d = 707.00
d' = 43.00
v = 0.00191815
    N = 16273.615
fc = 30.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01596533
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01596533
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.09711526

```

where  $f = af \cdot pf \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.31984848$$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff_e = 860.3348$$

$$f_y = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.31984848$$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff_e = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL \cdot t \cdot \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase_1 \cdot A_{ext} + ase_2 \cdot A_{int})/A_{sec} = 0.45746528$$

$$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) \cdot (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase_2 (\geq ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) \cdot (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$$

$$psh_x \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 3.31295$$

$$psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh_2 \text{ (5.4d)} = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 3.31295$$

$$psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh_2 \text{ ((5.4d), TBDY)} = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$$



Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 906.1344

fy1 = 755.112

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 755.112

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 896.8923

fy2 = 747.4102

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 747.4102

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025

shv = 0.008

ftv = 902.993

fyv = 752.4941

suv = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 752.4941

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.1965694

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.10018826

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.1780546

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00

```

fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is not satisfied
---->
v < vs,c - RHS eq.(4.5) is satisfied
---->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005

```

Calculation of ratio lb/l<sub>d</sub>

Adequate Lap Length: lb/l<sub>d</sub> >= 1

Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 995834.294$

Calculation of Shear Strength at edge 1,  $V_{r1} = 995834.294$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 995834.294$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

```

= 1 (normal-weight concrete)
Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.54545$ , but  $f'_c^{0.5} <=$ 
8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 30.38488
Vu = 0.00029699
d = 0.8*h = 600.00
Nu = 16273.615
Ag = 300000.00
From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$ 
where:
Vs,jacket = Vs,j1 + Vs,j2 = 903207.888
Vs,j1 = 314159.265 is calculated for section web jacket, with:
d = 320.00
Av = 157079.633
fy = 625.00
s = 100.00
Vs,j1 is multiplied by Col,j1 = 1.00
s/d = 0.3125
Vs,j2 = 589048.623 is calculated for section flange jacket, with:
d = 600.00
Av = 157079.633
fy = 625.00
s = 100.00
Vs,j2 is multiplied by Col,j2 = 1.00
s/d = 0.16666667
Vs,core = Vs,c1 + Vs,c2 = 92890.612
Vs,c1 = 0.00 is calculated for section web core, with:
d = 160.00
Av = 100530.965
fy = 525.00
s = 250.00

```

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$

$$s/d = 1.5625$$

$V_{s,c2} = 92890.612$  is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 525.00$$

$$s = 250.00$$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$

$$s/d = 0.56818182$$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $\theta$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$

$$b_w = 400.00$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Col0}$

$$V_{Col0} = 995834.294$$

$k_{nl} = 1$  (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:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 30.38458$$

$$V_u = 0.00029699$$

$$d = 0.8 \cdot h = 600.00$$

$$N_u = 16273.615$$

$$A_g = 300000.00$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$$

$V_{s,j1} = 314159.265$  is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 625.00$$

$$s = 100.00$$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$$s/d = 0.3125$$

$V_{s,j2} = 589048.623$  is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 625.00$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 525.00$$

$s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 92890.612$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In  $(11.3) \sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe}((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $b_w = 400.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At local axis: 2  
 -----

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
 At local axis: 3  
 Integration Section: (b)  
 Section Type: rcjlc

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 Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
 Concrete Elasticity,  $E_c = 23025.204$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_b/l_d \geq 1$ )

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

Bending Moment,  $M = 163137.319$

Shear Force,  $V_2 = 5348.301$

Shear Force,  $V_3 = -78.97309$

Axial Force,  $F = -17151.026$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1137.257$

-Compression:  $As_{l,com} = 2208.54$

-Middle:  $As_{l,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten,jacket} = 829.3805$

-Compression:  $As_{l,com,jacket} = 1746.726$

-Middle:  $As_{l,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten,core} = 307.8761$

-Compression:  $As_{l,com,core} = 461.8141$

-Middle:  $As_{l,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{R} = u = 0.00255981$

$u = y + p = 0.00255981$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.0004943$  ((4.29), Biskinis Phd))

$M_y = 7.0217E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4205E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.54545$

$N = 17151.026$

$E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

```

y = Min( y_ten, y_com)
y_ten = 5.2949365E-006
with fy = 601.9953
d = 707.00
y = 0.19595022
A = 0.01014948
B = 0.00445989
with pt = 0.0064556
pc = 0.00416509
pv = 0.00378591
N = 17151.026
b = 750.00
" = 0.06082037
y_comp = 1.5451003E-005
with fc* (12.3, (ACI 440)) = 30.48734
fc = 30.00
fl = 0.49678681
b = bmax = 750.00
h = hmax = 750.00
Ag = 0.44
g = pt + pc + pv = 0.01009575
rc = 40.00
Ae/Ac = 0.31291181
Effective FRP thickness, tf = NL*t*cos(b1) = 1.016
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 25742.96
y = 0.19514499
A = 0.01001989
B = 0.00440616
with Es = 200000.00
CONFIRMATION: y = 0.19595022 < t/d

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

- Calculation of p -

From table 10-8: p = 0.00206551

with:

- Columns not controlled by inadequate development or splicing along the clear height because lb/d >= 1

shear control ratio  $V_y E / V_{col} E = 1.21726$

d = d\_external = 707.00

s = s\_external = 0.00

-  $t = s_1 + s_2 + 2*tf/bw*(ffe/fs) = 0.0064556$

jacket:  $s_1 = A_{v1}*L_{stir1}/(s_1*Ag) = 0.00367709$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2}*L_{stir2}/(s_2*Ag) = 0.00067082$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2*tf/bw*(ffe/fs)$  is implemented to account for FRP contribution

where  $f = 2*tf/bw$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $ffe/fs$  normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation fs of jacket is used.

NUD = 17151.026

Ag = 440000.00

$f_{cE} = (f_{c\_jacket}*Area\_jacket + f_{c\_core}*Area\_core)/section\_area = 27.54545$

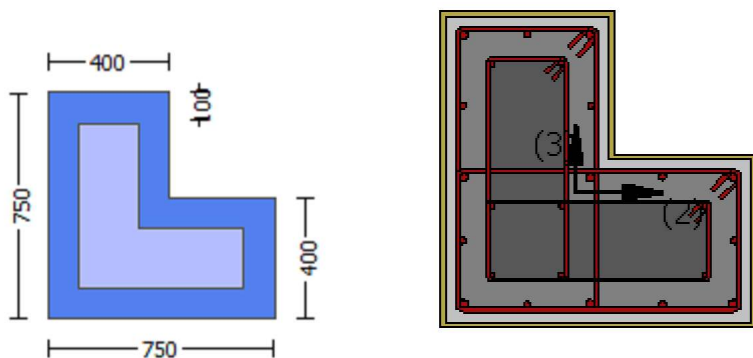
$f_{yE} = (f_{y\_ext\_Long\_Reinf}*Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf}*Area\_int\_Long\_Reinf)/Area\_Tot\_Long\_Rein = 601.9953$

$f_{ytE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 609.5715$   
 $p_l = Area\_Tot\_Long\_Rein / (b \cdot d) = 0.01009575$   
 $b = 750.00$   
 $d = 707.00$   
 $f_{cE} = 27.54545$

-----  
 End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
 At local axis: 3  
 Integration Section: (b)

## Calculation No. 9

column C1, Floor 1  
 Limit State: Life Safety (data interpolation between analysis steps 1 and 2)  
 Analysis: Uniform +X  
 Check: Shear capacity  $V_{Rd}$   
 Edge: Start  
 Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1  
 At local axis: 2  
 Integration Section: (a)  
 Section Type: rcjics

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 Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
 Concrete Elasticity,  $E_c = 25742.96$

```

Steel Elasticity, Es = 200000.00
Existing Column
Existing material of Primary Member: Concrete Strength, fc = fc_lower_bound = 16.00
Existing material of Primary Member: Steel Strength, fs = fs_lower_bound = 420.00
Concrete Elasticity, Ec = 23025.204
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of  $\mu_y$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, fc = fcm = 30.00
New material: Steel Strength, fs = fsm = 625.00
Existing Column
Existing material: Concrete Strength, fc = fcm = 24.00
Existing material: Steel Strength, fs = fsm = 525.00
#####
Max Height, Hmax = 750.00
Min Height, Hmin = 400.00
Max Width, Wmax = 750.00
Min Width, Wmin = 400.00
Jacket Thickness, tj = 100.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength,  $f_{fu}$  = 1055.00
Tensile Modulus,  $E_f$  = 64828.00
Elongation,  $ef_u$  = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

```

```

Stepwise Properties
-----
EDGE -A-
Bending Moment, Ma = -1.3021E+007
Shear Force, Va = -4295.351
EDGE -B-
Bending Moment, Mb = 131013.586
Shear Force, Vb = 4295.351
BOTH EDGES
Axial Force, F = -16978.285
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 5353.274
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1137.257
-Compression: Asl,com = 2208.54
-Middle: Asl,mid = 2007.478
Mean Diameter of Tension Reinforcement, DbL,ten = 16.80
-----

```

```

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity VR =  $*V_n$  = 813460.12
Vn ((10.3), ASCE 41-17) = knl*VCoIo = 813460.12

```



VCol = 813460.12  
 knl = 1.00  
 displacement\_ductility\_demand = 0.01057096

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:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 18.36364$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 1.3021E+007$   
 $V_u = 4295.351$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16978.285$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 796878.80$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 722566.31$   
 $V_{s,j1} = 251327.412$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,j2} = 471238.898$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 74312.489$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 420.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 74312.489$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 420.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 372533.843  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe}$  ((11-5), ACI 440) = 259.312  
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 683214.917$   
 $b_w = 400.00$

displacement\_ductility\_demand is calculated as  $\delta / y$

- Calculation of  $\delta / y$  for END A -  
for rotation axis 3 and integ. section (a)

From analysis, chord rotation  $\theta = 5.2793728E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.00499422$  ((4.29), Biskinis Phd))

$M_y = 7.0212E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3031.327

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4205E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.54545$

$N = 16978.285$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 5.2948555E-006$

with  $f_y = 601.9953$

$d = 707.00$

$y = 0.19593792$

$A = 0.01014894$

$B = 0.00445935$

with  $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 16978.285$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.5451339E-005$

with  $f_c' (12.3, (ACI 440)) = 30.48734$

$f_c = 30.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e/A_c = 0.31291181$

Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$

effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 25742.96$

$y = 0.19514075$

$A = 0.01002065$

$B = 0.00440616$

with  $E_s = 200000.00$

CONFIRMATION:  $y = 0.19593792 < t/d$

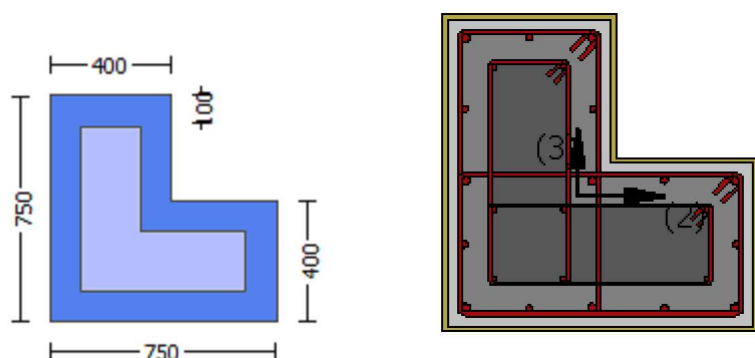
Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1  
At local axis: 2  
Integration Section: (a)

## Calculation No. 10

column C1, Floor 1  
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)  
Analysis: Uniform +X  
Check: Chord rotation capacity (  $\phi$  )  
Edge: Start  
Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
At Shear local axis: 3  
(Bending local axis: 2)  
Section Type: rcjcs

### Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
Concrete Elasticity,  $E_c = 25742.96$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
Concrete Elasticity,  $E_c = 23025.204$   
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,  $f_s = 1.25 \cdot f_{sm} = 781.25$ 
Existing Column
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$ 
#####
Max Height,  $H_{max} = 750.00$ 
Min Height,  $H_{min} = 400.00$ 
Max Width,  $W_{max} = 750.00$ 
Min Width,  $W_{min} = 400.00$ 
Jacket Thickness,  $t_j = 100.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.27105
Element Length,  $L = 3000.00$ 
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $\epsilon_{fu} = 0.01$ 
Number of directions,  $N_{oDir} = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $N_L = 1$ 
Radius of rounding corners,  $R = 40.00$ 
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Stepwise Properties
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At local axis: 3
EDGE -A-
Shear Force,  $V_a = -0.000297$ 
EDGE -B-
Shear Force,  $V_b = 0.000297$ 
BOTH EDGES
Axial Force,  $F = -16273.615$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
  -Tension:  $A_{slt} = 0.00$ 
  -Compression:  $A_{slc} = 5353.274$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
  -Tension:  $A_{sl,ten} = 1137.257$ 
  -Compression:  $A_{sl,com} = 2208.54$ 
  -Middle:  $A_{sl,mid} = 2007.478$ 
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Calculation of Shear Capacity ratio ,  $V_e/V_r = 1.21726$ 
Member Controlled by Shear ( $V_e/V_r > 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$ 
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.8183E+009$ 
 $\mu_{u1+} = 1.5436E+009$ , 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
 $\mu_{u1-} = 1.8183E+009$ , 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
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.8183E+009$ 
 $\mu_{u2+} = 1.5436E+009$ , 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
 $\mu_{u2-} = 1.8183E+009$ , 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 $\mu_{1+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 5.2115571E-005$$

$$\mu_{1+} = 1.5436E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\alpha_{1+} (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_{1+}: \mu_{1+}^* = \text{shear\_factor} * \text{Max}(\mu_{1+}, \alpha_{1+}) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{1+} = 0.01596533$$

$$\mu_{1+} \text{ (5.4c, TBDY)} = \alpha_{1+} * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$$

where  $f = \alpha_{1+} * \rho_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$f_y = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{1+} = 0.015$$

$$\alpha_{1+} \text{ (5.4d), TBDY} = (\alpha_{1+} * A_{\text{ext}} + \alpha_{1+} * A_{\text{int}})/A_{\text{sec}} = 0.45746528$$

$$\alpha_{1+} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{1+} (> \alpha_{1+}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max2}} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} \cdot F_{ywe} = \min(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 \text{ (5.4d)} = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.00471045$

$c = \text{confinement factor} = 1.27105$

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 896.8923$

$fy1 = 747.4102$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{min} = lb/l_d = 1.00$

$su1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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  $\min(1, 1.25 \cdot (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket} \cdot A_{sl,ten,jacket} + fs_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 747.4102$

with  $Es1 = (Es_{jacket} \cdot A_{sl,ten,jacket} + Es_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 906.1344$

$fy2 = 755.112$

$su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{min} = lb/l_b, min = 1.00$

$su2 = 0.4 \cdot esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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  $\min(1, 1.25 \cdot (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs_{jacket} \cdot A_{sl,com,jacket} + fs_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 755.112$

with  $Es2 = (Es_{jacket} \cdot A_{sl,com,jacket} + Es_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$

$yv = 0.0025$

$shv = 0.008$

$ftv = 902.993$

$fyv = 752.4941$

$suv = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lo_{u,min} = lb/ld = 1.00$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 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  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 752.4941$   
 with  $Esv = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.05343374$   
 $2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.10483702$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.09496245$

and confined core properties:

$b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.06065386$   
 $2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.11900291$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.10779406$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < vs_{y2}$  - LHS eq.(4.5) is not satisfied

--->  
 $v < vs_c$  - RHS eq.(4.5) is satisfied

--->  
 $su (4.8) = 0.13151351$   
 $Mu = MRc (4.15) = 1.5436E+009$   
 $u = su (4.1) = 5.2115571E-005$

Calculation of ratio  $lb/ld$

Adequate Lap Length:  $lb/ld \geq 1$

Calculation of  $Mu1$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 6.7707597E-005$   
 $Mu = 1.8183E+009$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00191815$   
 $N = 16273.615$   
 $fc = 30.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = shear\_factor * Max(cu, cc) = 0.01596533$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01596533$   
 $we ((5.4c), TBDY) = ase * sh_{min} * fy_{we} / fce + Min(fx, fy) = 0.09711526$   
 where  $f = af * pf * ffe / fce$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)  
 $fx = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff,e = 860.3348$

$f_y = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff,e = 860.3348$

$R = 40.00$

Effective FRP thickness,  $tf = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$ase((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int})/A_{sec} = 0.45746528$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) \cdot (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) \cdot (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2(5.4d) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2((5.4d), TBDY) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548



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Asec = 440000.00
s1 = 100.00
s2 = 250.00
fywe1 = 781.25
fywe2 = 656.25
fce = 30.00
From ((5.A.5), TBDY), TBDY: cc = 0.00471045
c = confinement factor = 1.27105
y1 = 0.0025
sh1 = 0.008
ft1 = 906.1344
fy1 = 755.112
su1 = 0.032
using (30) in Biskinis/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 = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 755.112
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 896.8923
fy2 = 747.4102
su2 = 0.032
using (30) in Biskinis/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 = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 747.4102
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105

```

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.2415059$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12309166$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.21875854$$

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied

$$\mu_u(4.8) = 0.3315127$$

$$M_u = M_{Rc}(4.15) = 1.8183E+009$$

$$u = \mu_u(4.1) = 6.7707597E-005$$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of  $\mu_{u2+}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 5.2115571E-005$$

$$M_u = 1.5436E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\alpha_{co}(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_{cu}: \mu_{cu}^* = \text{shear\_factor} * \text{Max}(\mu_{cu}, \alpha_{co}) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.01596533$$

$$\mu_{we}((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$$

where  $f = \alpha_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$$b_w = 400.00$$

effective stress from (A.35),  $f_{fe} = 860.3348$

$$f_y = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$$b_w = 400.00$$

effective stress from (A.35),  $f_{fe} = 860.3348$

$$R = 40.00$$

Effective FRP thickness,  $t_f = N L^* t \cos(b_1) = 1.016$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u,f = 0.015$$

$$ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.45746528$$

$$ase1 = \text{Max}(((Aconf,max1 - AnoConf1)/Aconf,max1)*(Aconf,min1/Aconf,max1), 0) = 0.45746528$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 293525.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>=ase1) = \text{Max}(((Aconf,max2 - AnoConf2)/Aconf,max2)*(Aconf,min2/Aconf,max2), 0) = 0.45746528$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.31295$$

$$psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$$

$$psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709$$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

$$psh2 (5.4d) = Lstir2*Astir2/(Asec*s2) = 0.00067082$$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

$$psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$$

$$psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709$$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

$$psh2 ((5.4d), TBDY) = Lstir2*Astir2/(Asec*s2) = 0.00067082$$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

$$Asec = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 781.25$$

$$fywe2 = 656.25$$

$$fce = 30.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00471045$$

$$c = \text{confinement factor} = 1.27105$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 896.8923$$

$$fy1 = 747.4102$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lo,min = lb/l_d = 1.00$$

$$su1 = 0.4*esu1\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 747.4102$$

```

with Es1 = (Esjacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 906.1344
fy2 = 755.112
su2 = 0.032
using (30) in Biskinis/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 = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 755.112
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.13151351
Mu = MRc (4.15) = 1.5436E+009
u = su (4.1) = 5.2115571E-005

```

Calculation of ratio lb/lb

Adequate Lap Length: lb/lb >= 1

Calculation of Mu2-

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 6.7707597E-005$$

$$\mu_u = 1.8183E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00191815$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\phi_{co} (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_{cu}: \phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01596533$$

$$\phi_{we} ((5.4c), TBDY) = a_{se} * \phi_{sh,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.09711526$$

where  $\phi_f = a_f * \phi_f^* * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$\phi_{fy} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.31295$

-----  
 $psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ (5.4d)} = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

-----  
 $psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

-----  
 $Asec = 440000.00$   
 $s1 = 100.00$   
 $s2 = 250.00$   
 $fywe1 = 781.25$   
 $fywe2 = 656.25$   
 $fce = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$

$y1 = 0.0025$   
 $sh1 = 0.008$   
 $ft1 = 906.1344$   
 $fy1 = 755.112$   
 $su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$

$lo/lou,min = lb/ld = 1.00$

$su1 = 0.4*esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 755.112$

with  $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$

$y2 = 0.0025$   
 $sh2 = 0.008$   
 $ft2 = 896.8923$   
 $fy2 = 747.4102$   
 $su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$

$lo/lou,min = lb/lb,min = 1.00$

$su2 = 0.4*esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 747.4102$

with  $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$

$yv = 0.0025$   
 $shv = 0.008$   
 $ftv = 902.993$   
 $fyv = 752.4941$   
 $suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $Min(1,1.25*(l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 752.4941$   
 with  $Esv = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.1965694$   
 $2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.10018826$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.1780546$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.2415059$   
 $2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.12309166$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.21875854$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $su (4.8) = 0.3315127$   
 $Mu = MRc (4.15) = 1.8183E+009$   
 $u = su (4.1) = 6.7707597E-005$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of Shear Strength  $V_r = Min(V_{r1}, V_{r2}) = 995834.294$

Calculation of Shear Strength at edge 1,  $V_{r1} = 995834.294$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.54545$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $Mu = 30.3689$   
 $Vu = 0.000297$   
 $d = 0.8 * h = 600.00$   
 $Nu = 16273.615$   
 $Ag = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 903207.888$   
 $V_{sj1} = 589048.623$  is calculated for section web jacket, with:  
 $d = 600.00$

$A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314159.265$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 92890.612$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$   
 $df_v = d$  (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:  $V_s + V_f \leq 836763.965$   
 $bw = 400.00$

-----  
 Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$   
 $V_{r2} = V_{Col}((10.3), ASCE 41-17) = knl \cdot V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $knl = 1$  (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:  $f'_c = (f'_c_{jacket} \cdot \text{Area}_{jacket} + f'_c_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 30.36921$   
 $V_u = 0.000297$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$   
 $V_{s,j1} = 589048.623$  is calculated for section web jacket, with:



$d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314159.265$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 92890.612$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / NoDir = 1.016$   
 $df_v = d$  (figure 11.2, ACI 440) = 707.00  
 $ffe((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $bw = 400.00$

-----  
 -----  
 End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At local axis: 3  
 -----

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjlc

Constant Properties

-----  
 Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
 Concrete Elasticity,  $E_c = 23025.204$   
 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,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.27105  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou}, \min > 1$ )  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$   
 -----

#### Stepwise Properties

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At local axis: 2  
 EDGE -A-  
 Shear Force,  $V_a = -0.00029699$   
 EDGE -B-  
 Shear Force,  $V_b = 0.00029699$   
 BOTH EDGES  
 Axial Force,  $F = -16273.615$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{slt} = 0.00$   
   -Compression:  $A_{slc} = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{sl,ten} = 1137.257$   
   -Compression:  $A_{sl,com} = 2208.54$   
   -Middle:  $A_{sl,mid} = 2007.478$   
 -----  
 -----

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.21726$   
 Member Controlled by Shear ( $V_e/V_r > 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$   
 with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.8183E+009$   
 $M_{u1+} = 1.5436E+009$ , 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

$Mu1- = 1.8183E+009$ , 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

$Mpr2 = \text{Max}(Mu2+, Mu2-) = 1.8183E+009$

$Mu2+ = 1.5436E+009$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu2- = 1.8183E+009$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $Mu1+$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 5.2115571E-005$

$Mu = 1.5436E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00102302$

$N = 16273.615$

$f_c = 30.00$

$\phi_{co} (5A.5, \text{TB DY}) = 0.002$

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01596533$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY:  $\phi_u = 0.01596533$

we ((5.4c), TB DY) =  $a_{se} * \phi_{u, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.09711526$

where  $\phi_x = a_f * \phi_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.0465966$

Expression ((15B.6), TB DY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$\phi_y = 0.0465966$

Expression ((15B.6), TB DY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$R = 40.00$

Effective FRP thickness,  $t_f = NL * t * \cos(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

$a_{se} ((5.4d), \text{TB DY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$

$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 3.31295$

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 3.31295  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00367709$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d)) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 3.31295  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00367709$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 896.8923

fy1 = 747.4102

su1 = 0.032

using (30) in Biskinis/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 = 1.00

su1 =  $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 747.4102$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.0025

sh2 = 0.008

ft2 = 906.1344

fy2 = 755.112

su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 =  $0.4 * esu2_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY:  $es_{u2\_nominal} = 0.08$ ,  
For calculation of  $es_{u2\_nominal}$  and  $y_2$ ,  $sh_2$ ,  $ft_2$ ,  $fy_2$ , it is considered  
characteristic value  $fs_{y2} = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 755.112$   
with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0025$   
 $sh_v = 0.008$   
 $ft_v = 902.993$   
 $fy_v = 752.4941$   
 $suv = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lou_{min} = lb/d = 1.00$   
 $suv = 0.4 \cdot es_{u2\_nominal} \cdot ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $es_{uv\_nominal} = 0.08$ ,  
considering characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY  
For calculation of  $es_{uv\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered  
characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 752.4941$   
with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.05343374$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.10483702$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.09496245$   
and confined core properties:  
 $b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc$  (5A.2, TBDY) = 38.13135  
 $cc$  (5A.5, TBDY) = 0.00471045  
 $c$  = confinement factor = 1.27105  
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.06065386$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.11900291$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.10779406$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)  
--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
--->  
 $su$  (4.8) = 0.13151351  
 $Mu = MRc$  (4.15) = 1.5436E+009  
 $u = su$  (4.1) = 5.2115571E-005

-----  
Calculation of ratio  $lb/d$

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Adequate Lap Length:  $lb/d \geq 1$   
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-----  
-----

Calculation of  $Mu_1$ -  
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-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 6.7707597E-005$   
 $Mu = 1.8183E+009$   
-----

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00191815$

$N = 16273.615$   
 $f_c = 30.00$   
 $\alpha (5A.5, TBDY) = 0.002$   
 Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01596533$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\alpha = 0.01596533$   
 $\alpha_e (5.4c, TBDY) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$   
 where  $f = \alpha * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0465966$   
 Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$   
 $\alpha_f = 0.31984848$   
 with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$   
 $b_{\max} = 750.00$   
 $h_{\max} = 750.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{f,e} = 860.3348$

$f_y = 0.0465966$   
 Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$   
 $\alpha_f = 0.31984848$   
 with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$   
 $b_{\max} = 750.00$   
 $h_{\max} = 750.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{f,e} = 860.3348$

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{f,f} = 0.015$

$\alpha_{se} (5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$   
 $\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $p_{sh,min} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 3.31295$

$p_{sh,x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{s2} * f_{ywe2} = 3.31295$   
 $p_{sh1} (5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 3.31295  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00367709  
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00067082  
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A.5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 906.1344

fy1 = 755.112

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 755.112

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 896.8923

fy2 = 747.4102

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 747.4102

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025

shv = 0.008

ftv = 902.993

fyv = 752.4941

suv = 0.032

using (30) in Biskinis/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 = 1.00

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 = 752.4941

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

```

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

```

```

--->
v < vs,y2 - LHS eq.(4.5) is not satisfied

```

```

--->
v < vs,c - RHS eq.(4.5) is satisfied

```

```

--->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

```

u = 5.2115571E-005
Mu = 1.5436E+009

```

with full section properties:

```

b = 750.00
d = 707.00
d' = 43.00
v = 0.00102302
N = 16273.615
fc = 30.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01596533
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01596533
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.09711526
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

```

```

fx = 0.0465966
Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)
af = 0.31984848
with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 140733.333
bmax = 750.00
hmax = 750.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00508
bw = 400.00
effective stress from (A.35), ffe = 860.3348

```

```

fy = 0.0465966
Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)
af = 0.31984848
with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 140733.333

```



bmax = 750.00  
hmax = 750.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$   
bw = 400.00  
effective stress from (A.35),  $ff,e = 860.3348$

R = 40.00  
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.45746528$

$ase1 = Max(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = Max(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{,min} * F_{ywe} = Min(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 3.31295$

$psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2(5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

$c$  = confinement factor = 1.27105

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 896.8923$

$fy1 = 747.4102$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,  
 For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = (fs_{jacket} * A_{s,ten,jacket} + fs_{core} * A_{s,ten,core}) / A_{s,ten} = 747.4102$   
 with  $Es_1 = (Es_{jacket} * A_{s,ten,jacket} + Es_{core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$   
 $y_2 = 0.0025$   
 $sh_2 = 0.008$   
 $ft_2 = 906.1344$   
 $fy_2 = 755.112$   
 $su_2 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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.  
 $y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * A_{s,com,jacket} + fs_{core} * A_{s,com,core}) / A_{s,com} = 755.112$   
 with  $Es_2 = (Es_{jacket} * A_{s,com,jacket} + Es_{core} * A_{s,com,core}) / A_{s,com} = 200000.00$   
 $y_v = 0.0025$   
 $sh_v = 0.008$   
 $ft_v = 902.993$   
 $fy_v = 752.4941$   
 $suv = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * A_{s,mid,jacket} + fs_{mid} * A_{s,mid,core}) / A_{s,mid} = 752.4941$   
 with  $Es_v = (Es_{jacket} * A_{s,mid,jacket} + Es_{mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b * d) * (fs_1 / fc) = 0.05343374$   
 $2 = A_{s,com} / (b * d) * (fs_2 / fc) = 0.10483702$   
 $v = A_{s,mid} / (b * d) * (fsv / fc) = 0.09496245$   
 and confined core properties:  
 $b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = A_{s,ten} / (b * d) * (fs_1 / fc) = 0.06065386$   
 $2 = A_{s,com} / (b * d) * (fs_2 / fc) = 0.11900291$   
 $v = A_{s,mid} / (b * d) * (fsv / fc) = 0.10779406$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $su (4.8) = 0.13151351$   
 $Mu = MRc (4.15) = 1.5436E+009$   
 $u = su (4.1) = 5.2115571E-005$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of  $\mu_2$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 6.7707597E-005$$

$$\mu_2 = 1.8183E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$\nu = 0.00191815$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\alpha_0 \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear\_factor} * \text{Max}(\mu_2, \alpha_0) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_2 = 0.01596533$$

$$\mu_2 \text{ (5.4c), TBDY} = \alpha_0 * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$$

where  $f = \alpha_f * \rho_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$f_y = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY)} = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-AnoConf2)/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$   
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.  
AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min * Fywe = \text{Min}(psh,x * Fywe, psh,y * Fywe) = 3.31295$

$psh,x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
 $psh1 ((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d)) = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

$psh,y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
 $psh1 ((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 906.1344

fy1 = 755.112

su1 = 0.032

using (30) in Biskinis/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 = 1.00

su1 = 0.4 \* esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket \* Asl,ten,jacket + fs,core \* Asl,ten,core) / Asl,ten = 755.112

with Es1 = (Es,jacket \* Asl,ten,jacket + Es,core \* Asl,ten,core) / Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 896.8923

fy2 = 747.4102

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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  $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 747.4102$   
 with  $Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.0025$   
 $shv = 0.008$   
 $ftv = 902.993$   
 $fyv = 752.4941$   
 $suv = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou, min = lb/ld = 1.00$   
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 752.4941$   
 with  $Esv = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.1965694$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.10018826$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.1780546$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.2415059$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.12309166$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.21875854$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$  - LHS eq.(4.5) is not satisfied

--->

$v < vs,c$  - RHS eq.(4.5) is satisfied

--->

$su (4.8) = 0.3315127$

$Mu = MRc (4.15) = 1.8183E+009$

$u = su (4.1) = 6.7707597E-005$

Calculation of ratio  $lb/ld$

Adequate Lap Length:  $lb/ld \geq 1$

Calculation of Shear Strength  $Vr = \text{Min}(Vr1, Vr2) = 995834.294$

Calculation of Shear Strength at edge 1,  $Vr1 = 995834.294$

$Vr1 = VCol ((10.3), ASCE 41-17) = knl \cdot VCol0$

$VCol0 = 995834.294$

$knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $Vs = Av \cdot fy \cdot d / s$ ' is replaced by ' $Vs + f \cdot Vf$ '  
 where  $Vf$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.54545$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu = 30.38488$   
 $V_u = 0.00029699$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$   
 $V_{s,j1} = 314159.265$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,j2} = 589048.623$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 92890.612$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot)\sin\alpha$  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:  $\alpha = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $k_{nl} = 1$  (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).

$\gamma = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.54545$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$   
 $\mu_u = 30.38458$   
 $V_u = 0.00029699$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 903207.888$   
 $V_{sj1} = 314159.265$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.3125$   
 $V_{sj2} = 589048.623$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 92890.612$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $b_w = 400.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At local axis: 2  
 -----

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
 At local axis: 2  
 Integration Section: (a)  
 Section Type: rcjcs

## 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 Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_b/l_d \geq 1$ )

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $ef_u = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $bi: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

Bending Moment,  $M = -140135.355$

Shear Force,  $V_2 = -4295.351$

Shear Force,  $V_3 = 63.42516$

Axial Force,  $F = -16978.285$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1137.257$

-Compression:  $As_{l,com} = 2208.54$

-Middle:  $As_{l,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten,jacket} = 829.3805$

-Compression:  $As_{l,com,jacket} = 1746.726$

-Middle:  $As_{l,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten,core} = 307.8761$

-Compression:  $As_{l,com,core} = 461.8141$

-Middle:  $As_{l,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$



Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = \frac{1}{2} u = 0.04119349$   
 $u = y + p = 0.04119349$

- Calculation of  $y$  -

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00364017$  ((4.29), Biskinis Phd))  
 $M_y = 7.0212E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 2209.46  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 1.4205E+014$   
 $factor = 0.30$   
 $A_g = 440000.00$   
Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.54545$   
 $N = 16978.285$   
 $E_c \cdot I_g = E_{c,jacket} \cdot I_{g,jacket} + E_{c,core} \cdot I_{g,core} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$   
web width,  $b_w = 400.00$   
flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 5.2948555E-006$   
with  $f_y = 601.9953$   
 $d = 707.00$   
 $y = 0.19593792$   
 $A = 0.01014894$   
 $B = 0.00445935$   
with  $p_t = 0.0064556$   
 $p_c = 0.00416509$   
 $p_v = 0.00378591$   
 $N = 16978.285$   
 $b = 750.00$   
 $" = 0.06082037$   
 $y_{comp} = 1.5451339E-005$   
with  $f_c' (12.3, (ACI 440)) = 30.48734$   
 $f_c = 30.00$   
 $f_l = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $rc = 40.00$   
 $A_e/A_c = 0.31291181$   
Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 25742.96$   
 $y = 0.19514075$   
 $A = 0.01002065$   
 $B = 0.00440616$   
with  $E_s = 200000.00$   
CONFIRMATION:  $y = 0.19593792 < t/d$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

- Calculation of  $p$  -

From table 10-8:  $p = 0.03755332$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/l_d \geq 1$

shear control ratio  $V_{yE}/V_{CoIE} = 1.21726$

$d = d_{\text{external}} = 707.00$

$s = s_{\text{external}} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f/bw \cdot (f_{fe}/f_s) = 0.0064556$

jacket:  $s_1 = A_{v1} \cdot L_{\text{stir1}}/(s_1 \cdot A_g) = 0.00367709$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{\text{stir1}} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot L_{\text{stir2}}/(s_2 \cdot A_g) = 0.00067082$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{\text{stir2}} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2 \cdot t_f/bw \cdot (f_{fe}/f_s)$  is implemented to account for FRP contribution

where  $f = 2 \cdot t_f/bw$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe}/f_s$  normalises  $f$  to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 16978.285$

$A_g = 440000.00$

$f_{cE} = (f_{c,jacket} \cdot A_{\text{jacket}} + f_{c,core} \cdot A_{\text{core}})/\text{section\_area} = 27.54545$

$f_{yE} = (f_{y,ext\_Long\_Reinf} \cdot A_{\text{ext\_Long\_Reinf}} + f_{y,int\_Long\_Reinf} \cdot A_{\text{int\_Long\_Reinf}})/A_{\text{Tot\_Long\_Rein}} = 601.9953$

$f_{yE} = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2)/(s_1 + s_2) = 609.5715$

$p_l = A_{\text{Tot\_Long\_Rein}}/(b \cdot d) = 0.01009575$

$b = 750.00$

$d = 707.00$

$f_{cE} = 27.54545$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 11

column C1, Floor 1

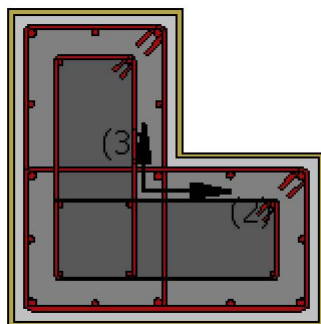
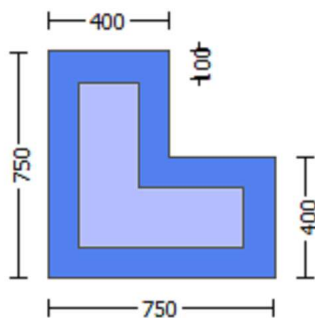
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjlcs

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 Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_c = f_{cm} = 30.00$

New material: Steel Strength,  $f_s = f_{sm} = 625.00$

Existing Column

Existing material: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )

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°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

#### Stepwise Properties

EDGE -A-  
Bending Moment, Ma = -140135.355  
Shear Force, Va = 63.42516  
EDGE -B-  
Bending Moment, Mb = -48804.308  
Shear Force, Vb = -63.42516  
BOTH EDGES  
Axial Force, F = -16978.285  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 5353.274  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 1137.257  
-Compression: Asl,com = 2208.54  
-Middle: Asl,mid = 2007.478  
Mean Diameter of Tension Reinforcement, DbL,ten = 16.80

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity VR = \*Vn = 824692.24  
Vn ((10.3), ASCE 41-17) = knl\*VColO = 824692.24  
VCol = 824692.24  
knl = 1.00  
displacement\_ductility\_demand = 0.00566446

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 = 18.36364, but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
M/Vd = 3.68243  
Mu = 140135.355  
Vu = 63.42516  
d = 0.8\*h = 600.00  
Nu = 16978.285  
Ag = 300000.00  
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 796878.80  
where:  
Vs,jacket = Vs,j1 + Vs,j2 = 722566.31  
Vs,j1 = 471238.898 is calculated for section web jacket, with:  
d = 600.00  
Av = 157079.633  
fy = 500.00  
s = 100.00  
Vs,j1 is multiplied by Col,j1 = 1.00  
s/d = 0.16666667  
Vs,j2 = 251327.412 is calculated for section flange jacket, with:  
d = 320.00  
Av = 157079.633  
fy = 500.00  
s = 100.00  
Vs,j2 is multiplied by Col,j2 = 1.00  
s/d = 0.3125  
Vs,core = Vs,c1 + Vs,c2 = 74312.489  
Vs,c1 = 74312.489 is calculated for section web core, with:  
d = 440.00  
Av = 100530.965

$f_y = 420.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 420.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$   
 $df_v = d$  (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:  $V_s + V_f \leq 683214.917$   
 $bw = 400.00$

displacement\_ductility\_demand is calculated as  $\delta / y$

- Calculation of  $\delta / y$  for END A -  
 for rotation axis 2 and integ. section (a)

From analysis, chord rotation  $\theta = 2.0619572E-005$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00364017$  ((4.29), Biskinis Phd))  
 $M_y = 7.0212E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 2209.46  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.4205E+014$   
 $\text{factor} = 0.30$   
 $A_g = 440000.00$   
 Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.54545$   
 $N = 16978.285$   
 $E_c \cdot I_g = E_{c,\text{jacket}} \cdot I_{g,\text{jacket}} + E_{c,\text{core}} \cdot I_{g,\text{core}} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$   
 web width,  $bw = 400.00$   
 flange thickness,  $t = 400.00$

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 5.2948555E-006$   
 with  $f_y = 601.9953$   
 $d = 707.00$   
 $y = 0.19593792$   
 $A = 0.01014894$   
 $B = 0.00445935$   
 with  $pt = 0.00214476$   
 $pc = 0.00416509$

$p_v = 0.00378591$   
 $N = 16978.285$   
 $b = 750.00$   
 $" = 0.06082037$   
 $y_{comp} = 1.5451339E-005$   
 with  $f_c^* (12.3, (ACI 440)) = 30.48734$   
 $f_c = 30.00$   
 $f_l = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $rc = 40.00$   
 $A_e/A_c = 0.31291181$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 25742.96$   
 $y = 0.19514075$   
 $A = 0.01002065$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.19593792 < t/d$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 12

column C1, Floor 1

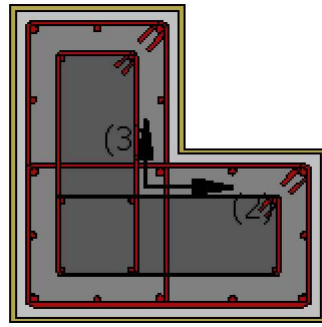
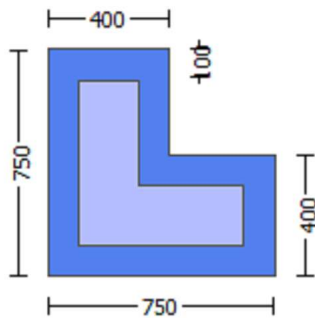
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\phi$  )

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.27105

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )

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,  $b_i = 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -0.000297$

EDGE -B-

Shear Force,  $V_b = 0.000297$

BOTH EDGES

Axial Force,  $F = -16273.615$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1137.257$

-Compression:  $As_{c,com} = 2208.54$

-Middle:  $As_{mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.21726$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$  with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.8183E+009$

$Mu_{1+} = 1.5436E+009$ , 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

$Mu_{1-} = 1.8183E+009$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.8183E+009$

$Mu_{2+} = 1.5436E+009$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 1.8183E+009$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $Mu_{1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 5.2115571E-005$

$Mu = 1.5436E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00102302$

$N = 16273.615$

$f_c = 30.00$

$\phi_{co} (5A.5, \text{TB DY}) = 0.002$

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01596533$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY:  $\phi_u = 0.01596533$

we ((5.4c), TB DY)  $= a_s e^* \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.09711526$

where  $\phi_f = a_f * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.0465966$

Expression ((15B.6), TB DY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area  $= ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$



From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00508$   
 $bw = 400.00$   
effective stress from (A.35),  $ff,e = 860.3348$

$f_y = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff,e = 860.3348$

$R = 40.00$

Effective FRP thickness,  $tf = NL \cdot t \cdot \cos(b1) = 1.016$

$f_u, f = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$

$ase ((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.45746528$

$ase1 = \text{Max}(((A_{conf, \max 1} - A_{noConf1}) / A_{conf, \max 1}) \cdot (A_{conf, \min 1} / A_{conf, \max 1}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf, \min 1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf, \max 1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf, \max 2} - A_{noConf2}) / A_{conf, \max 2}) \cdot (A_{conf, \min 2} / A_{conf, \max 2}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf, \min 2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf, \max 2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{\min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d)) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

```

fce = 30.00
From ((5.A5), TBDY), TBDY: cc = 0.00471045
c = confinement factor = 1.27105
y1 = 0.0025
sh1 = 0.008
ft1 = 896.8923
fy1 = 747.4102
su1 = 0.032
using (30) in Biskinis/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 = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 747.4102
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 906.1344
fy2 = 755.112
su2 = 0.032
using (30) in Biskinis/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 = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 755.112
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

```

```

---->
v < vs,y2 - LHS eq.(4.5) is not satisfied
---->
v < vs,c - RHS eq.(4.5) is satisfied
---->
su (4.8) = 0.13151351
Mu = MRc (4.15) = 1.5436E+009
u = su (4.1) = 5.2115571E-005

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:  
u = 6.7707597E-005  
Mu = 1.8183E+009

with full section properties:

b = 400.00  
d = 707.00  
d' = 43.00  
v = 0.00191815  
N = 16273.615

fc = 30.00  
co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01596533

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01596533

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.09711526

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.0465966

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.31984848

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 140733.333

bmax = 750.00

hmax = 750.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00508

bw = 400.00

effective stress from (A.35), ffe = 860.3348

fy = 0.0465966

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.31984848

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 140733.333

bmax = 750.00

hmax = 750.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00508

bw = 400.00

effective stress from (A.35), ffe = 860.3348

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 = 0.45746528

ase1 = Max(((Aconf,max1-AnoConf1)/Aconf,max1)\*(Aconf,min1/Aconf,max1),0) = 0.45746528

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.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and  
 is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and  
 is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length  
 equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization  
 of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)  
 "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and  
 is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and  
 is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length  
 equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.31295$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

$c$  = confinement factor = 1.27105

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 906.1344$

$fy1 = 755.112$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 755.112$

with  $Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 896.8923$

$fy2 = 747.4102$

```

su2 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 747.4102
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
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 = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 5.2115571E-005

Mu = 1.5436E+009

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\alpha (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \alpha = 0.01596533$$

$$\alpha_c ((5.4c), \text{TB DY}) = \alpha_{se} * \alpha_{h,min} * f_{ywe} / f_{ce} + \text{Min}(\alpha_x, \alpha_y) = 0.09711526$$

where  $\alpha = \alpha^* p_f^* f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\alpha_x = 0.0465966$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$\alpha_y = 0.0465966$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_u, f = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$\alpha_{se} ((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 3.31295$$

$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

$Asec = 440000.00$   
 $s1 = 100.00$   
 $s2 = 250.00$   
 $fywe1 = 781.25$   
 $fywe2 = 656.25$   
 $fce = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$

$y1 = 0.0025$   
 $sh1 = 0.008$   
 $ft1 = 896.8923$   
 $fy1 = 747.4102$   
 $su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$

$lo/lou, min = lb/ld = 1.00$

$su1 = 0.4 * esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs\_jacket * Asl, ten, jacket + fs\_core * Asl, ten, core) / Asl, ten = 747.4102$

with  $Es1 = (Es\_jacket * Asl, ten, jacket + Es\_core * Asl, ten, core) / Asl, ten = 200000.00$

$y2 = 0.0025$   
 $sh2 = 0.008$   
 $ft2 = 906.1344$   
 $fy2 = 755.112$   
 $su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$

$lo/lou, min = lb/lb, min = 1.00$

$su2 = 0.4 * esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$

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.

$y2, sh2, ft2, fy2$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs\_jacket * Asl, com, jacket + fs\_core * Asl, com, core) / Asl, com = 755.112$

with  $Es2 = (Es\_jacket * Asl, com, jacket + Es\_core * Asl, com, core) / Asl, com = 200000.00$

$yv = 0.0025$   
 $shv = 0.008$   
 $ftv = 902.993$   
 $fyv = 752.4941$   
 $suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$

$lo/lou, min = lb/ld = 1.00$

$suv = 0.4 * esuv\_nominal \text{ ((5.5), TBDY)} = 0.032$

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  $e_{suv\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered  
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{sl,mid,jacket} + f_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 752.4941$

with  $E_{sv} = (E_{s,jacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$

$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1}/f_c) = 0.05343374$

$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2}/f_c) = 0.10483702$

$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv}/f_c) = 0.09496245$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 38.13135

$cc$  (5A.5, TBDY) = 0.00471045

$c$  = confinement factor = 1.27105

$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1}/f_c) = 0.06065386$

$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2}/f_c) = 0.11900291$

$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv}/f_c) = 0.10779406$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

---->

$v < v_{s,c}$  - RHS eq.(4.5) is satisfied

---->

$su$  (4.8) = 0.13151351

$Mu = MR_c$  (4.15) = 1.5436E+009

$u = su$  (4.1) = 5.2115571E-005

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of  $Mu_2$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 6.7707597E-005$

$Mu = 1.8183E+009$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00191815$

$N = 16273.615$

$f_c = 30.00$

$co$  (5A.5, TBDY) = 0.002

Final value of  $cu$ :  $cu^* = \text{shear\_factor} \cdot \text{Max}(cu, cc) = 0.01596533$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $cu = 0.01596533$

$w_e$  ((5.4c), TBDY) =  $ase \cdot sh_{min} \cdot fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.09711526$

where  $f = af \cdot pf \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$fx = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$



effective stress from (A.35),  $f_{f,e} = 860.3348$

$f_y = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{f,e} = 860.3348$

$R = 40.00$

Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$a_{se} ((5.4d), TBDY) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int})/A_{sec} = 0.45746528$

$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) \cdot (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) \cdot (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 3.31295$

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 3.31295$

$p_{sh1} ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2} ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 3.31295$

$p_{sh1} ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2} ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

```

c = confinement factor = 1.27105
y1 = 0.0025
sh1 = 0.008
ft1 = 906.1344
fy1 = 755.112
su1 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 755.112
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 896.8923
fy2 = 747.4102
su2 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 747.4102
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
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 = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied

```

```

--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005
-----

Calculation of ratio lb/ld
-----

Adequate Lap Length: lb/ld >= 1
-----
-----
-----

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 995834.294
-----

Calculation of Shear Strength at edge 1, Vr1 = 995834.294
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 995834.294
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*Areajacket + fc'core*Areacore)/Areasection = 27.54545, but fc'0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 30.3689
Vu = 0.000297
d = 0.8*h = 600.00
Nu = 16273.615
Ag = 300000.00
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 996098.499
where:
Vs,jacket = Vs,j1 + Vs,j2 = 903207.888
Vs,j1 = 589048.623 is calculated for section web jacket, with:
d = 600.00
Av = 157079.633
fy = 625.00
s = 100.00
Vs,j1 is multiplied by Colj1 = 1.00
s/d = 0.16666667
Vs,j2 = 314159.265 is calculated for section flange jacket, with:
d = 320.00
Av = 157079.633
fy = 625.00
s = 100.00
Vs,j2 is multiplied by Colj2 = 1.00
s/d = 0.3125
Vs,core = Vs,c1 + Vs,c2 = 92890.612
Vs,c1 = 92890.612 is calculated for section web core, with:
d = 440.00
Av = 100530.965
fy = 525.00
s = 250.00
Vs,c1 is multiplied by Colc1 = 1.00
s/d = 0.56818182
Vs,c2 = 0.00 is calculated for section flange core, with:
d = 160.00
Av = 100530.965
fy = 525.00
s = 250.00
Vs,c2 is multiplied by Colc2 = 0.00
s/d = 1.5625
Vf ((11-3)-(11.4), ACI 440) = 372533.843

```

$f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , 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,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$   
 $V_{r2} = V_{Col}((10.3), \text{ASCE 41-17}) = knl \cdot V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $knl = 1$  (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).

$f = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot \text{Area}_{jacket} + f'_{c\_core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 30.36921$   
 $\nu_u = 0.000297$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$   
 $V_{s,j1} = 589048.623$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314159.265$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 92890.612$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$

Vf ((11-3)-(11.4), ACI 440) = 372533.843

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf( , ), is implemented for every different fiber orientation ai, as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$

Vf = Min(|Vf(45,  $\theta_1$ )|, |Vf(-45,  $\theta_1$ )|), with:

total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$

dfv = d (figure 11.2, ACI 440) = 707.00

ffe ((11-5), ACI 440) = 259.312

Ef = 64828.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.01

From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$

bw = 400.00

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjlc

Constant Properties

Knowledge Factor,  $\phi = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 * f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 * f_{sm} = 656.25$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.27105

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou, min} \geq 1$ )

#### FRP Wrapping Data

Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i = 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = -0.00029699$   
EDGE -B-  
Shear Force,  $V_b = 0.00029699$   
BOTH EDGES  
Axial Force,  $F = -16273.615$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 5353.274$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1137.257$   
-Compression:  $A_{sl,com} = 2208.54$   
-Middle:  $A_{sl,mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.21726$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$  with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.8183E+009$

$\mu_{u1+} = 1.5436E+009$ , 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

$\mu_{u1-} = 1.8183E+009$ , 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

$M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.8183E+009$

$\mu_{u2+} = 1.5436E+009$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u2-} = 1.8183E+009$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $\mu_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 5.2115571E-005$

$\mu_u = 1.5436E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00102302$

$N = 16273.615$

$f_c = 30.00$

$\phi_o$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_o) = 0.01596533$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.01596533$   
 $w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$   
 where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

---


$$f_x = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 860.3348$$

---


$$f_y = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 860.3348$$

---


$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.31295$$

---


$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.31295$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00367709$$

$$L_{stir1} (\text{Length of stirrups along Y}) = 2060.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} (5.4d) = L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00067082$$

$$L_{stir2} (\text{Length of stirrups along Y}) = 1468.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

---


$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.31295$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00367709$$

$$L_{stir1} (\text{Length of stirrups along X}) = 2060.00$$

Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
 Lstir2 (Length of stirrups along X) = 1468.00  
 Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 896.8923

fy1 = 747.4102

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 747.4102

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 906.1344

fy2 = 755.112

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 755.112

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025

shv = 0.008

ftv = 902.993

fyv = 752.4941

suv = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 752.4941

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.05343374

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.10483702

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.09496245

and confined core properties:

b = 690.00



$d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.06065386$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11900291$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.10779406$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->

$s_u (4.8) = 0.13151351$   
 $M_u = M_{Rc} (4.15) = 1.5436E+009$   
 $u = s_u (4.1) = 5.2115571E-005$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of  $M_{u1}$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 6.7707597E-005$   
 $M_u = 1.8183E+009$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00191815$   
 $N = 16273.615$   
 $f_c = 30.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01596533$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01596533$   
 $w_e ((5.4c), TBDY) = a_{se} * sh_{min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$   
 where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$f_y = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_f = 0.015$$

$$ase((5.4d), \text{TB DY}) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.45746528$$

$$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.31295$$

$$psh_x * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 3.31295$$

$$psh_1 ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$$psh_2 (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$$psh_y * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 3.31295$$

$$psh_1 ((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$$psh_2 ((5.4d), \text{TB DY}) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$$A_{sec} = 440000.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

$$f_{ywe1} = 781.25$$

$$f_{ywe2} = 656.25$$

$$f_{ce} = 30.00$$

$$\text{From } ((5.A5), \text{TB DY}), \text{TB DY: } cc = 0.00471045$$

$$c = \text{confinement factor} = 1.27105$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 906.1344$$

$$fy_1 = 755.112$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$$l_o / l_{ou,min} = l_b / d = 1.00$$

$$su_1 = 0.4 * esu_1_{nominal} ((5.5), \text{TB DY}) = 0.032$$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = (fs\_jacket \cdot Asl\_ten\_jacket + fs\_core \cdot Asl\_ten\_core) / Asl\_ten = 755.112$   
with  $Es1 = (Es\_jacket \cdot Asl\_ten\_jacket + Es\_core \cdot Asl\_ten\_core) / Asl\_ten = 200000.00$   
 $y2 = 0.0025$   
 $sh2 = 0.008$   
 $ft2 = 896.8923$   
 $fy2 = 747.4102$   
 $su2 = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/lb, min = 1.00$   
 $su2 = 0.4 \cdot esu2\_nominal \cdot ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs2 = (fs\_jacket \cdot Asl\_com\_jacket + fs\_core \cdot Asl\_com\_core) / Asl\_com = 747.4102$   
with  $Es2 = (Es\_jacket \cdot Asl\_com\_jacket + Es\_core \cdot Asl\_com\_core) / Asl\_com = 200000.00$   
 $yv = 0.0025$   
 $shv = 0.008$   
 $ftv = 902.993$   
 $fyv = 752.4941$   
 $suv = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/ld = 1.00$   
 $suv = 0.4 \cdot esuv\_nominal \cdot ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs\_jacket \cdot Asl\_mid\_jacket + fs\_mid \cdot Asl\_mid\_core) / Asl\_mid = 752.4941$   
with  $Es_v = (Es\_jacket \cdot Asl\_mid\_jacket + Es\_mid \cdot Asl\_mid\_core) / Asl\_mid = 200000.00$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.1965694$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.10018826$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.1780546$   
and confined core properties:  
 $b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.2415059$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.12309166$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.21875854$   
Case/Assumption: Unconfined full section - Steel rupture  
'satisfies Eq. (4.3)  
--->  
 $v < vs, y2$  - LHS eq.(4.5) is not satisfied  
--->  
 $v < vs, c$  - RHS eq.(4.5) is satisfied  
--->  
 $su (4.8) = 0.3315127$   
 $Mu = MRc (4.15) = 1.8183E+009$   
 $u = su (4.1) = 6.7707597E-005$

Calculation of ratio  $lb/ld$

Adequate Lap Length:  $lb/ld \geq 1$

## Calculation of $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 5.2115571\text{E-}005$$

$$\mu_{\mu} = 1.5436\text{E+}009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\alpha_{\text{co}} (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_{\text{cu}}: \mu_{\text{cu}}^* = \text{shear\_factor} * \text{Max}(\mu_{\text{cu}}, \alpha_{\text{co}}) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{\text{cu}} = 0.01596533$$

$$\mu_{\text{we}} ((5.4c), \text{TBDY}) = \alpha_{\text{se}} * \mu_{\text{sh,min}} * f_{y\text{we}} / f_{\text{ce}} + \text{Min}(\mu_{\text{fx}}, \mu_{\text{fy}}) = 0.09711526$$

where  $\mu_{\text{f}} = \alpha_{\text{f}} * \mu_{\text{p}} * f_{\text{fe}} / f_{\text{ce}}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{\text{fx}} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_{\text{f}} = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_{\text{f}} = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{\text{pf}} = 2t_{\text{f}} / b_{\text{w}} = 0.00508$$

$$b_{\text{w}} = 400.00$$

$$\text{effective stress from (A.35), } f_{\text{fe}} = 860.3348$$

$$\mu_{\text{fy}} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_{\text{f}} = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_{\text{f}} = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{\text{pf}} = 2t_{\text{f}} / b_{\text{w}} = 0.00508$$

$$b_{\text{w}} = 400.00$$

$$\text{effective stress from (A.35), } f_{\text{fe}} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_{\text{f}} = N L^* t \cos(b_1) = 1.016$$

$$f_{\text{u,f}} = 1055.00$$

$$E_{\text{f}} = 64828.00$$

$$\mu_{\text{u,f}} = 0.015$$

$$\alpha_{\text{se}} ((5.4d), \text{TBDY}) = (\alpha_{\text{se1}} * A_{\text{ext}} + \alpha_{\text{se2}} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\alpha_{\text{se1}} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{\text{se2}} (>= \alpha_{\text{se1}}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.31295$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.00471045$

$c = \text{confinement factor} = 1.27105$

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 896.8923$

$fy1 = 747.4102$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{min} = lb/ld = 1.00$

$su1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$

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  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 747.4102$

with  $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 906.1344$

$fy2 = 755.112$

$su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{min} = lb/lb_{min} = 1.00$

$su2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$

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  $fs2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 755.112$

with  $Es2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$

$yv = 0.0025$

```

shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
    using (30) in Biskinis/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 = 1.00
    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 = 752.4941
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
    2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
    v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
    c = confinement factor = 1.27105
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
    2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
    v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.13151351
Mu = MRc (4.15) = 1.5436E+009
u = su (4.1) = 5.2115571E-005

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

```

u = 6.7707597E-005
Mu = 1.8183E+009

```

with full section properties:

```

b = 400.00
d = 707.00
d' = 43.00
v = 0.00191815
    N = 16273.615
fc = 30.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01596533
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01596533
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.09711526

```

where  $f = af \cdot pf \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.31984848$$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff_e = 860.3348$$

$$f_y = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.31984848$$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff_e = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL \cdot t \cdot \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase_1 \cdot A_{ext} + ase_2 \cdot A_{int})/A_{sec} = 0.45746528$$

$$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) \cdot (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) \cdot (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{,min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$$

$$psh_x \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 3.31295$$

$$psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh_2 \text{ (5.4d)} = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 3.31295$$

$$psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh_2 \text{ ((5.4d), TBDY)} = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$$

Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 906.1344

fy1 = 755.112

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 755.112

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 896.8923

fy2 = 747.4102

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 747.4102

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025

shv = 0.008

ftv = 902.993

fyv = 752.4941

suv = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 752.4941

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.1965694

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.10018826

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.1780546

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00



```

fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 995834.294$

Calculation of Shear Strength at edge 1,  $V_{r1} = 995834.294$

$V_{r1} = V_{Col} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 995834.294$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

```

= 1 (normal-weight concrete)
Mean concrete strength:  $f'_c = (f'_{c,jacket} * \text{Area}_{jacket} + f'_{c,core} * \text{Area}_{core}) / \text{Area}_{section} = 27.54545$ , but  $f'_c^{0.5} <=$ 
8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 30.38488
Vu = 0.00029699
d = 0.8*h = 600.00
Nu = 16273.615
Ag = 300000.00
From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$ 
where:
Vs,jacket = Vs,j1 + Vs,j2 = 903207.888
Vs,j1 = 314159.265 is calculated for section web jacket, with:
d = 320.00
Av = 157079.633
fy = 625.00
s = 100.00
Vs,j1 is multiplied by Col,j1 = 1.00
s/d = 0.3125
Vs,j2 = 589048.623 is calculated for section flange jacket, with:
d = 600.00
Av = 157079.633
fy = 625.00
s = 100.00
Vs,j2 is multiplied by Col,j2 = 1.00
s/d = 0.16666667
Vs,core = Vs,c1 + Vs,c2 = 92890.612
Vs,c1 = 0.00 is calculated for section web core, with:
d = 160.00
Av = 100530.965
fy = 525.00
s = 250.00

```

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$

$$s/d = 1.5625$$

$V_{s,c2} = 92890.612$  is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 525.00$$

$$s = 250.00$$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$

$$s/d = 0.56818182$$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $\theta$ , 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,  $t_{f1} = N_L * t / N_{Dir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$

$$b_w = 400.00$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$

$$V_{Col0} = 995834.294$$

$k_{nl} = 1$  (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:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 30.38458$$

$$V_u = 0.00029699$$

$$d = 0.8 * h = 600.00$$

$$N_u = 16273.615$$

$$A_g = 300000.00$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$$

$V_{s,j1} = 314159.265$  is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 625.00$$

$$s = 100.00$$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$$s/d = 0.3125$$

$V_{s,j2} = 589048.623$  is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 625.00$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 525.00$$

$s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 92890.612$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In  $(11.3) \sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , 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,  $tf1 = NL * t / NoDir = 1.016$   
 $dfv = d$  (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:  $V_s + V_f \leq 836763.965$   
 $bw = 400.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At local axis: 2  
 -----

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
 At local axis: 3  
 Integration Section: (a)  
 Section Type: rcjics

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 Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
 Concrete Elasticity,  $E_c = 23025.204$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_b/l_d \geq 1$ )

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

Bending Moment,  $M = -1.3021E+007$

Shear Force,  $V_2 = -4295.351$

Shear Force,  $V_3 = 63.42516$

Axial Force,  $F = -16978.285$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1137.257$

-Compression:  $As_{l,com} = 2208.54$

-Middle:  $As_{l,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten,jacket} = 829.3805$

-Compression:  $As_{l,com,jacket} = 1746.726$

-Middle:  $As_{l,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten,core} = 307.8761$

-Compression:  $As_{l,com,core} = 461.8141$

-Middle:  $As_{l,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{R} = u = 0.04254755$

$u = y + p = 0.04254755$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00499422$  ((4.29), Biskinis Phd))

$M_y = 7.0212E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3031.327

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4205E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.54545$

$N = 16978.285$

$E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

```

y = Min( y_ten, y_com)
y_ten = 5.2948555E-006
with fy = 601.9953
d = 707.00
y = 0.19593792
A = 0.01014894
B = 0.00445935
with pt = 0.0064556
pc = 0.00416509
pv = 0.00378591
N = 16978.285
b = 750.00
" = 0.06082037
y_comp = 1.5451339E-005
with fc* (12.3, (ACI 440)) = 30.48734
fc = 30.00
fl = 0.49678681
b = bmax = 750.00
h = hmax = 750.00
Ag = 0.44
g = pt + pc + pv = 0.01009575
rc = 40.00
Ae/Ac = 0.31291181
Effective FRP thickness, tf = NL*t*cos(b1) = 1.016
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 25742.96
y = 0.19514075
A = 0.01002065
B = 0.00440616
with Es = 200000.00
CONFIRMATION: y = 0.19593792 < t/d

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

- Calculation of p -

From table 10-8: p = 0.03755332

with:

- Columns not controlled by inadequate development or splicing along the clear height because lb/d >= 1

shear control ratio  $V_y E / V_{col} E = 1.21726$

d = d\_external = 707.00

s = s\_external = 0.00

-  $t = s_1 + s_2 + 2*tf/bw*(ffe/fs) = 0.0064556$

jacket:  $s_1 = A_{v1}*L_{stir1}/(s_1*Ag) = 0.00367709$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2}*L_{stir2}/(s_2*Ag) = 0.00067082$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2*tf/bw*(ffe/fs)$  is implemented to account for FRP contribution

where  $f = 2*tf/bw$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $ffe/fs$  normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation fs of jacket is used.

NUD = 16978.285

Ag = 440000.00

$f_{cE} = (f_{c\_jacket}*Area\_jacket + f_{c\_core}*Area\_core)/section\_area = 27.54545$

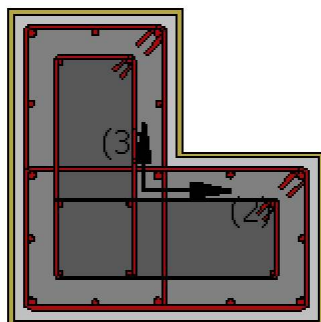
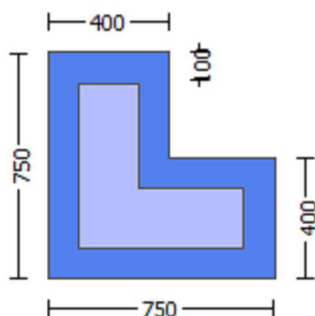
$f_{yE} = (f_{y\_ext\_Long\_Reinf}*Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf}*Area\_int\_Long\_Reinf)/Area\_Tot\_Long\_Rein = 601.9953$

$f_{ytE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 609.5715$   
 $p_l = Area\_Tot\_Long\_Rein / (b \cdot d) = 0.01009575$   
 $b = 750.00$   
 $d = 707.00$   
 $f_{cE} = 27.54545$

-----  
 End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
 At local axis: 3  
 Integration Section: (a)

## Calculation No. 13

column C1, Floor 1  
 Limit State: Life Safety (data interpolation between analysis steps 1 and 2)  
 Analysis: Uniform +X  
 Check: Shear capacity  $VR_d$   
 Edge: End  
 Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjlcs

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 Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
 Concrete Elasticity,  $E_c = 25742.96$

```

Steel Elasticity, Es = 200000.00
Existing Column
Existing material of Primary Member: Concrete Strength, fc = fc_lower_bound = 16.00
Existing material of Primary Member: Steel Strength, fs = fs_lower_bound = 420.00
Concrete Elasticity, Ec = 23025.204
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of  $\mu_y$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, fc = fcm = 30.00
New material: Steel Strength, fs = fsm = 625.00
Existing Column
Existing material: Concrete Strength, fc = fcm = 24.00
Existing material: Steel Strength, fs = fsm = 525.00
#####
Max Height, Hmax = 750.00
Min Height, Hmin = 400.00
Max Width, Wmax = 750.00
Min Width, Wmin = 400.00
Jacket Thickness, tj = 100.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength,  $f_{fu}$  = 1055.00
Tensile Modulus,  $E_f$  = 64828.00
Elongation,  $ef_u$  = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

```

```

Stepwise Properties
-----
EDGE -A-
Bending Moment, Ma = -1.3021E+007
Shear Force, Va = -4295.351
EDGE -B-
Bending Moment, Mb = 131013.586
Shear Force, Vb = 4295.351
BOTH EDGES
Axial Force, F = -16978.285
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 5353.274
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1137.257
-Compression: Asl,com = 2208.54
-Middle: Asl,mid = 2007.478
Mean Diameter of Tension Reinforcement, DbL,ten = 16.80
-----

```

```

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity VR =  $*V_n$  = 943705.324
Vn ((10.3), ASCE 41-17) = knl*VCoIo = 943705.324

```

$$V_{Col} = 943705.324$$

$$k_{nl} = 1.00$$

$$\text{displacement\_ductility\_demand} = 0.0283752$$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 18.36364$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 131013.586$$

$$V_u = 4295.351$$

$$d = 0.8 \cdot h = 600.00$$

$$N_u = 16978.285$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 796878.80$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 722566.31$$

$V_{s,j1} = 251327.412$  is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 500.00$$

$$s = 100.00$$

$V_{s,j1}$  is multiplied by  $Col_{j1} = 1.00$

$$s/d = 0.3125$$

$V_{s,j2} = 471238.898$  is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 500.00$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col_{j2} = 1.00$

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 74312.489$$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 420.00$$

$$s = 250.00$$

$V_{s,c1}$  is multiplied by  $Col_{c1} = 0.00$

$$s/d = 1.5625$$

$V_{s,c2} = 74312.489$  is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 420.00$$

$$s = 250.00$$

$V_{s,c2}$  is multiplied by  $Col_{c2} = 1.00$

$$s/d = 0.56818182$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 372533.843$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$  (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.

$$\text{orientation 1: } \theta_1 = \theta_1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L \cdot t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 707.00$$

$$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 683214.917$$

$$b_w = 400.00$$



displacement\_ductility\_demand is calculated as  $\delta / y$

- Calculation of  $\delta / y$  for END B -  
for rotation axis 3 and integ. section (b)

From analysis, chord rotation  $\theta = 1.4024761E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.00049426$  ((4.29), Biskinis Phd))

$M_y = 7.0212E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4205E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.54545$

$N = 16978.285$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 5.2948555E-006$

with  $f_y = 601.9953$

$d = 707.00$

$y = 0.19593792$

$A = 0.01014894$

$B = 0.00445935$

with  $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 16978.285$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.5451339E-005$

with  $f_c' (12.3, (ACI 440)) = 30.48734$

$f_c = 30.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e/A_c = 0.31291181$

Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$

effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 25742.96$

$y = 0.19514075$

$A = 0.01002065$

$B = 0.00440616$

with  $E_s = 200000.00$

CONFIRMATION:  $y = 0.19593792 < t/d$

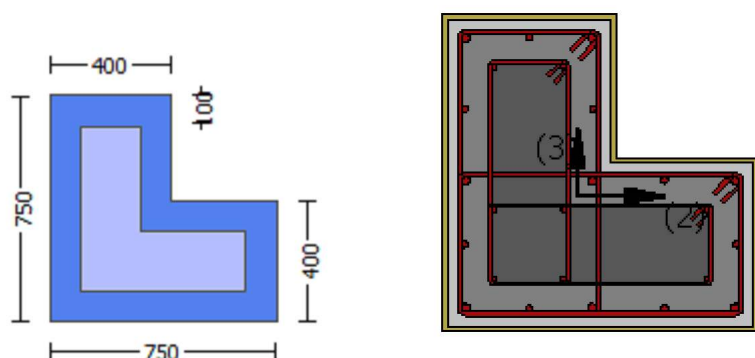
Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)

## Calculation No. 14

column C1, Floor 1  
 Limit State: Life Safety (data interpolation between analysis steps 1 and 2)  
 Analysis: Uniform +X  
 Check: Chord rotation capacity (  $\phi$  )  
 Edge: End  
 Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At Shear local axis: 3  
 (Bending local axis: 2)  
 Section Type: rcjcs

### Constant Properties

Knowledge Factor,  $\gamma = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
 Concrete Elasticity,  $E_c = 23025.204$   
 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,  $f_s = 1.25 \cdot f_{sm} = 781.25$ 
Existing Column
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$ 
#####
Max Height,  $H_{max} = 750.00$ 
Min Height,  $H_{min} = 400.00$ 
Max Width,  $W_{max} = 750.00$ 
Min Width,  $W_{min} = 400.00$ 
Jacket Thickness,  $t_j = 100.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.27105
Element Length,  $L = 3000.00$ 
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $\epsilon_{fu} = 0.01$ 
Number of directions,  $N_{oDir} = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $N_L = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
At local axis: 3
EDGE -A-
Shear Force,  $V_a = -0.000297$ 
EDGE -B-
Shear Force,  $V_b = 0.000297$ 
BOTH EDGES
Axial Force,  $F = -16273.615$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
  -Tension:  $A_{sl,t} = 0.00$ 
  -Compression:  $A_{sl,c} = 5353.274$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
  -Tension:  $A_{sl,ten} = 1137.257$ 
  -Compression:  $A_{sl,com} = 2208.54$ 
  -Middle:  $A_{sl,mid} = 2007.478$ 
-----
-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 1.21726$ 
Member Controlled by Shear ( $V_e/V_r > 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$ 
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.8183E+009$ 
 $\mu_{u1+} = 1.5436E+009$ , 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
 $\mu_{u1-} = 1.8183E+009$ , 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
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.8183E+009$ 
 $\mu_{u2+} = 1.5436E+009$ , 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
 $\mu_{u2-} = 1.8183E+009$ , 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:

$$\mu = 5.2115571E-005$$

$$\mu_u = 1.5436E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\alpha_{co} (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_{cu}: \mu_{cu}^* = \text{shear\_factor} * \text{Max}(\mu_{cu}, \alpha_{co}) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.01596533$$

$$\mu_{we} ((5.4c), TBDY) = \alpha_{se} * \mu_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.09711526$$

where  $\mu_f = \alpha_f * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{fx} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$\mu_{fy} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

$$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{conf, \max 1} - A_{noConf1}) / A_{conf, \max 1}) * (A_{conf, \min 1} / A_{conf, \max 1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf, \min 1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf, \max 1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{conf, \max 2} - A_{noConf2}) / A_{conf, \max 2}) * (A_{conf, \min 2} / A_{conf, \max 2}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} \cdot F_{ywe} = \min(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 \text{ (5.4d)} = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

$c$  = confinement factor = 1.27105

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 896.8923$

$fy1 = 747.4102$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{min} = lb/l_d = 1.00$

$su1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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  $\min(1, 1.25 \cdot (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket} \cdot A_{sl,ten,jacket} + fs_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 747.4102$

with  $Es1 = (Es_{jacket} \cdot A_{sl,ten,jacket} + Es_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 906.1344$

$fy2 = 755.112$

$su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{min} = lb/l_b, min = 1.00$

$su2 = 0.4 \cdot esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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  $\min(1, 1.25 \cdot (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs_{jacket} \cdot A_{sl,com,jacket} + fs_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 755.112$

with  $Es2 = (Es_{jacket} \cdot A_{sl,com,jacket} + Es_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 902.993$

$fy_v = 752.4941$

$suv = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lo_{u,min} = lb/ld = 1.00$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 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  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 752.4941$   
 with  $Esv = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.05343374$   
 $2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.10483702$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.09496245$

and confined core properties:

$b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.06065386$   
 $2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.11900291$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.10779406$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < vs,y2$  - LHS eq.(4.5) is not satisfied

--->  
 $v < vs,c$  - RHS eq.(4.5) is satisfied

--->  
 $su (4.8) = 0.13151351$   
 $Mu = MRc (4.15) = 1.5436E+009$   
 $u = su (4.1) = 5.2115571E-005$

Calculation of ratio  $lb/ld$

Adequate Lap Length:  $lb/ld \geq 1$

Calculation of  $Mu1$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 6.7707597E-005$   
 $Mu = 1.8183E+009$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00191815$   
 $N = 16273.615$   
 $fc = 30.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = shear\_factor * Max(cu, cc) = 0.01596533$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01596533$   
 $we ((5.4c), TBDY) = ase * sh_{min} * fy_{we} / fce + Min(fx, fy) = 0.09711526$   
 where  $f = af * pf * ffe / fce$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)  
 $fx = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff,e = 860.3348$

$f_y = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff,e = 860.3348$

$R = 40.00$

Effective FRP thickness,  $tf = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$ase((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int})/A_{sec} = 0.45746528$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) \cdot (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) \cdot (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2(5.4d) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2((5.4d), TBDY) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

```

Asec = 440000.00
s1 = 100.00
s2 = 250.00
fywe1 = 781.25
fywe2 = 656.25
fce = 30.00
From ((5.A.5), TBDY), TBDY: cc = 0.00471045
c = confinement factor = 1.27105
y1 = 0.0025
sh1 = 0.008
ft1 = 906.1344
fy1 = 755.112
su1 = 0.032
using (30) in Biskinis/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 = 1.00
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  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 755.112
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 896.8923
fy2 = 747.4102
su2 = 0.032
using (30) in Biskinis/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 = 1.00
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  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 747.4102
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
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  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105

```



$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.2415059$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12309166$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.21875854$$

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied

$$\mu_u(4.8) = 0.3315127$$

$$\mu_u = M_{Rc}(4.15) = 1.8183E+009$$

$$u = \mu_u(4.1) = 6.7707597E-005$$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of  $\mu_{u2+}$

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 5.2115571E-005$$

$$\mu_u = 1.5436E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\alpha_{co}(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_{cu}: \mu_{cu}^* = \text{shear\_factor} * \text{Max}(\mu_{cu}, \alpha_{co}) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.01596533$$

$$\mu_{we}((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_{fx}, f_{fy}) = 0.09711526$$

where  $f = \alpha_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_{fx} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$f_{fy} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u,f = 0.015$$

$$ase((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.45746528$$

$$ase1 = \text{Max}(((Aconf,max1 - AnoConf1)/Aconf,max1)*(Aconf,min1/Aconf,max1), 0) = 0.45746528$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 293525.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((Aconf,max2 - AnoConf2)/Aconf,max2)*(Aconf,min2/Aconf,max2), 0) = 0.45746528$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.31295$$

$$psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$$

$$psh1((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709$$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

$$psh2(5.4d) = Lstir2*Astir2/(Asec*s2) = 0.00067082$$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

$$psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$$

$$psh1((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709$$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

$$psh2((5.4d), TBDY) = Lstir2*Astir2/(Asec*s2) = 0.00067082$$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

$$Asec = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 781.25$$

$$fywe2 = 656.25$$

$$fce = 30.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00471045$$

$$c = \text{confinement factor} = 1.27105$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 896.8923$$

$$fy1 = 747.4102$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lo,min = lb/ld = 1.00$$

$$su1 = 0.4*esu1\_nominal((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 747.4102$$

```

with Es1 = (Esjacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 906.1344
fy2 = 755.112
su2 = 0.032
using (30) in Biskinis/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 = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fsjacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 755.112
with Es2 = (Esjacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.
with fsv = (fsjacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 752.4941
with Esv = (Esjacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.13151351
Mu = MRc (4.15) = 1.5436E+009
u = su (4.1) = 5.2115571E-005

```

Calculation of ratio lb/lb

Adequate Lap Length: lb/lb >= 1

Calculation of Mu2-

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 6.7707597E-005$$

$$\mu_u = 1.8183E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$\nu = 0.00191815$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\phi_{co} (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_{cu}: \phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01596533$$

$$\phi_{we} ((5.4c), TBDY) = a_{se} * \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.09711526$$

where  $\phi_f = a_f * \phi_f^* * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$\phi_{fy} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} \cdot Fywe = \text{Min}(psh_x \cdot Fywe, psh_y \cdot Fywe) = 3.31295$

---

$psh_x \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ (5.4d)} = Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

$psh_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 3.31295$   
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

---

$Asec = 440000.00$   
 $s1 = 100.00$   
 $s2 = 250.00$   
 $fywe1 = 781.25$   
 $fywe2 = 656.25$   
 $fce = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$

$y1 = 0.0025$   
 $sh1 = 0.008$   
 $ft1 = 906.1344$   
 $fy1 = 755.112$   
 $su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou_{min} = lb/ld = 1.00$

$su1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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.

with  $fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 755.112$

with  $Es1 = (Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$

$y2 = 0.0025$   
 $sh2 = 0.008$   
 $ft2 = 896.8923$   
 $fy2 = 747.4102$   
 $su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou_{min} = lb/lb_{min} = 1.00$

$su2 = 0.4 \cdot esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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.

with  $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 747.4102$

with  $Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

$yv = 0.0025$   
 $shv = 0.008$   
 $ftv = 902.993$   
 $fyv = 752.4941$   
 $suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 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  $Min(1,1.25*(l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs\_jacket * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 752.4941$   
 with  $Esv = (Es\_jacket * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.1965694$   
 $2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.10018826$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.1780546$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.2415059$   
 $2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.12309166$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.21875854$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $su (4.8) = 0.3315127$   
 $Mu = MRc (4.15) = 1.8183E+009$   
 $u = su (4.1) = 6.7707597E-005$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of Shear Strength  $V_r = Min(V_{r1}, V_{r2}) = 995834.294$

Calculation of Shear Strength at edge 1,  $V_{r1} = 995834.294$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$

$V_{Col0} = 995834.294$

$knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.54545$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $Mu = 30.3689$   
 $Vu = 0.000297$   
 $d = 0.8 * h = 600.00$   
 $Nu = 16273.615$   
 $Ag = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 903207.888$   
 $V_{sj1} = 589048.623$  is calculated for section web jacket, with:  
 $d = 600.00$

$A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314159.265$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 92890.612$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$   
 $df_v = d$  (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:  $V_s + V_f \leq 836763.965$   
 $bw = 400.00$

-----  
 Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$   
 $V_{r2} = V_{Col}((10.3), ASCE 41-17) = knl \cdot V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $knl = 1$  (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:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 30.36921$   
 $V_u = 0.000297$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$   
 $V_{s,j1} = 589048.623$  is calculated for section web jacket, with:

$d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314159.265$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 92890.612$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL * t / NoDir = 1.016$   
 $df_v = d$  (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:  $V_s + V_f \leq 836763.965$   
 $bw = 400.00$

-----  
 -----  
 End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At local axis: 3  
 -----

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjls

Constant Properties

-----  
 Knowledge Factor,  $\gamma = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$



Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
 Concrete Elasticity,  $E_c = 23025.204$   
 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,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.27105  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou}, \min > 1$ )  
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $\epsilon_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$   
 -----

#### Stepwise Properties

-----

At local axis: 2  
 EDGE -A-  
 Shear Force,  $V_a = -0.00029699$   
 EDGE -B-  
 Shear Force,  $V_b = 0.00029699$   
 BOTH EDGES  
 Axial Force,  $F = -16273.615$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $A_{slt} = 0.00$   
 -Compression:  $A_{slc} = 5353.274$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $A_{sl,ten} = 1137.257$   
 -Compression:  $A_{sl,com} = 2208.54$   
 -Middle:  $A_{sl,mid} = 2007.478$   
 -----  
 -----

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.21726$   
 Member Controlled by Shear ( $V_e/V_r > 1$ )  
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$   
 with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.8183E+009$   
 $M_{u1+} = 1.5436E+009$ , 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

$Mu1- = 1.8183E+009$ , 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

$Mpr2 = \text{Max}(Mu2+, Mu2-) = 1.8183E+009$

$Mu2+ = 1.5436E+009$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu2- = 1.8183E+009$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $Mu1+$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 5.2115571E-005$

$Mu = 1.5436E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00102302$

$N = 16273.615$

$f_c = 30.00$

$\phi_{co} (5A.5, \text{TB DY}) = 0.002$

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01596533$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY:  $\phi_u = 0.01596533$

we ((5.4c), TB DY) =  $a_{se} * \phi_{u, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.09711526$

where  $\phi_x = a_f * \phi_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.0465966$

Expression ((15B.6), TB DY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$\phi_y = 0.0465966$

Expression ((15B.6), TB DY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $\phi_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$R = 40.00$

Effective FRP thickness,  $t_f = NL * t * \cos(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

$a_{se} ((5.4d), \text{TB DY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$

$a_{se1} = \text{Max}(((A_{conf, \max 1} - A_{noConf1}) / A_{conf, \max 1}) * (A_{conf, \min 1} / A_{conf, \max 1}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf, \min}$  and  $A_{conf, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf, \min 1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
ase2 ( $\geq$  ase1) =  $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min\*Fywe =  $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 3.31295$

psh\_x\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 3.31295  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00367709$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 (5.4d) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1 + ps2\*Fywe2 = 3.31295  
psh1 ((5.4d), TBDY) =  $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00367709$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) =  $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 896.8923

fy1 = 747.4102

su1 = 0.032

using (30) in Biskinis/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 = 1.00

su1 =  $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 747.4102$

with Es1 =  $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.0025

sh2 = 0.008

ft2 = 906.1344

fy2 = 755.112

su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 =  $0.4 * esu2_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY:  $es_{u2\_nominal} = 0.08$ ,  
For calculation of  $es_{u2\_nominal}$  and  $y_2$ ,  $sh_2$ ,  $ft_2$ ,  $fy_2$ , it is considered  
characteristic value  $fs_{y2} = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 755.112$   
with  $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $y_v = 0.0025$   
 $sh_v = 0.008$   
 $ft_v = 902.993$   
 $fy_v = 752.4941$   
 $s_{uv} = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00  
 $lo/lo_{u,min} = lb/ld = 1.00$   
 $s_{uv} = 0.4 \cdot es_{uv\_nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $es_{uv\_nominal} = 0.08$ ,  
considering characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY  
For calculation of  $es_{uv\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered  
characteristic value  $fs_{yv} = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 752.4941$   
with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.05343374$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.10483702$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.09496245$   
and confined core properties:  
 $b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.06065386$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.11900291$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.10779406$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)  
--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
--->  
 $su (4.8) = 0.13151351$   
 $Mu = MRc (4.15) = 1.5436E+009$   
 $u = su (4.1) = 5.2115571E-005$

-----  
Calculation of ratio  $lb/ld$   
-----

Adequate Lap Length:  $lb/ld \geq 1$   
-----  
-----  
-----

Calculation of  $Mu_1$ -  
-----  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 6.7707597E-005$   
 $Mu = 1.8183E+009$   
-----

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00191815$

$N = 16273.615$   
 $f_c = 30.00$   
 $\alpha (5A.5, TBDY) = 0.002$   
 Final value of  $\alpha$ :  $\alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01596533$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\alpha = 0.01596533$   
 $\alpha_e (5.4c, TBDY) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$   
 where  $f = \alpha * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0465966$   
 Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$   
 $\alpha_f = 0.31984848$   
 with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$   
 $b_{\max} = 750.00$   
 $h_{\max} = 750.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{fe} = 860.3348$

$f_y = 0.0465966$   
 Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$   
 $\alpha_f = 0.31984848$   
 with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$   
 $b_{\max} = 750.00$   
 $h_{\max} = 750.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{fe} = 860.3348$

$R = 40.00$   
 Effective FRP thickness,  $t_f = N L * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$

$\alpha_{se} (5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$   
 $\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.  
 $A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.  
 $A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $\alpha_{se2} (> \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$   
 The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
 $A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
 $A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.  
 $A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $p_{sh,min} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 3.31295$

$p_{sh,x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{s2} * f_{ywe2} = 3.31295$   
 $p_{sh1} (5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 3.31295  
psh1 ((5.4d), TBDY) = Lstir1\*Astir1/(Asec\*s1) = 0.00367709  
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
psh2 ((5.4d), TBDY) = Lstir2\*Astir2/(Asec\*s2) = 0.00067082  
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A.5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 906.1344

fy1 = 755.112

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 755.112

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 896.8923

fy2 = 747.4102

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 747.4102

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025

shv = 0.008

ftv = 902.993

fyv = 752.4941

suv = 0.032

using (30) in Biskinis/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 = 1.00

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 = 752.4941

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

```

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

```

```

--->
v < vs,y2 - LHS eq.(4.5) is not satisfied

```

```

--->
v < vs,c - RHS eq.(4.5) is satisfied

```

```

--->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

```

u = 5.2115571E-005
Mu = 1.5436E+009

```

with full section properties:

```

b = 750.00
d = 707.00
d' = 43.00
v = 0.00102302
N = 16273.615
fc = 30.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01596533
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01596533
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.09711526
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

```

```

fx = 0.0465966
Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)
af = 0.31984848
with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 140733.333
bmax = 750.00
hmax = 750.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00508
bw = 400.00
effective stress from (A.35), ffe = 860.3348

```

```

fy = 0.0465966
Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)
af = 0.31984848
with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 140733.333

```

bmax = 750.00  
hmax = 750.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00508$   
bw = 400.00  
effective stress from (A.35),  $ff,e = 860.3348$

R = 40.00  
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.45746528$

$ase1 = Max(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = Max(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{,min} * F_{ywe} = Min(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 3.31295$

$psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2(5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

$c$  = confinement factor = 1.27105

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 896.8923$

$fy1 = 747.4102$

$su1 = 0.032$



using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,  
 For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = (fs_{jacket} * A_{s,ten,jacket} + fs_{core} * A_{s,ten,core}) / A_{s,ten} = 747.4102$   
 with  $Es_1 = (Es_{jacket} * A_{s,ten,jacket} + Es_{core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$   
 $y_2 = 0.0025$   
 $sh_2 = 0.008$   
 $ft_2 = 906.1344$   
 $fy_2 = 755.112$   
 $su_2 = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * A_{s,com,jacket} + fs_{core} * A_{s,com,core}) / A_{s,com} = 755.112$   
 with  $Es_2 = (Es_{jacket} * A_{s,com,jacket} + Es_{core} * A_{s,com,core}) / A_{s,com} = 200000.00$   
 $y_v = 0.0025$   
 $sh_v = 0.008$   
 $ft_v = 902.993$   
 $fy_v = 752.4941$   
 $suv = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * A_{s,mid,jacket} + fs_{mid} * A_{s,mid,core}) / A_{s,mid} = 752.4941$   
 with  $Es_v = (Es_{jacket} * A_{s,mid,jacket} + Es_{mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b * d) * (fs_1 / fc) = 0.05343374$   
 $2 = A_{s,com} / (b * d) * (fs_2 / fc) = 0.10483702$   
 $v = A_{s,mid} / (b * d) * (fsv / fc) = 0.09496245$   
 and confined core properties:  
 $b = 690.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = A_{s,ten} / (b * d) * (fs_1 / fc) = 0.06065386$   
 $2 = A_{s,com} / (b * d) * (fs_2 / fc) = 0.11900291$   
 $v = A_{s,mid} / (b * d) * (fsv / fc) = 0.10779406$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $su (4.8) = 0.13151351$   
 $Mu = MRc (4.15) = 1.5436E+009$   
 $u = su (4.1) = 5.2115571E-005$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of  $\mu_2$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 6.7707597E-005$$

$$\mu = 1.8183E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00191815$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\alpha (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \mu = 0.01596533$$

$$\text{we ((5.4c), TB DY) } = \alpha * \text{sh\_min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$$

where  $f = \alpha * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0465966$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$f_y = 0.0465966$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} ((5.4d), \text{TB DY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>=ase1) = \text{Max}(((A_{conf,max2}-AnoConf2)/A_{conf,max2})*(A_{conf,min2}/A_{conf,max2}),0) = 0.45746528$   
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).  
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."  
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.  
Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.  
Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.  
AnoConf2 = 106242.667 is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.31295$

$psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$   
 $psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709$   
Lstir1 (Length of stirrups along Y) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d)) = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
Lstir2 (Length of stirrups along Y) = 1468.00  
Astir2 (stirrups area) = 50.26548

$psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.31295$   
 $psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709$   
Lstir1 (Length of stirrups along X) = 2060.00  
Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2*Astir2/(Asec*s2) = 0.00067082$   
Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 906.1344

fy1 = 755.112

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25*(lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 755.112

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 896.8923

fy2 = 747.4102

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{s2} = (f_{sjacket} \cdot A_{sl,com,jacket} + f_{s,core} \cdot A_{sl,com,core})/A_{sl,com} = 747.4102$   
 with  $E_{s2} = (E_{sjacket} \cdot A_{sl,com,jacket} + E_{s,core} \cdot A_{sl,com,core})/A_{sl,com} = 200000.00$   
 $y_v = 0.0025$   
 $sh_v = 0.008$   
 $ft_v = 902.993$   
 $f_{y_v} = 752.4941$   
 $s_{u_v} = 0.032$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $s_{u_v} = 0.4 \cdot e_{s_{u_v,nominal}} ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $e_{s_{u_v,nominal}} = 0.08$ ,  
 considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $e_{s_{u_v,nominal}}$  and  $y_v, sh_v, ft_v, f_{y_v}$ , it is considered  
 characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{sv} = (f_{sjacket} \cdot A_{sl,mid,jacket} + f_{s,mid} \cdot A_{sl,mid,core})/A_{sl,mid} = 752.4941$   
 with  $E_{sv} = (E_{sjacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core})/A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1965694$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.10018826$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.1780546$

and confined core properties:

$b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, \text{TBDY}) = 38.13135$   
 $cc (5A.5, \text{TBDY}) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.2415059$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12309166$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.21875854$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$  - RHS eq.(4.5) is satisfied

--->

$s_u (4.8) = 0.3315127$

$\mu_u = M_{Rc} (4.15) = 1.8183E+009$

$u = s_u (4.1) = 6.7707597E-005$

Calculation of ratio  $l_b/l_d$

Adequate Lap Length:  $l_b/l_d \geq 1$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 995834.294$

Calculation of Shear Strength at edge 1,  $V_{r1} = 995834.294$

$V_{r1} = V_{Col} ((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{Col0}$

$V_{Col0} = 995834.294$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d/s$ ' is replaced by ' $V_s + f \cdot V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core})/\text{Area}_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu = 30.38488$   
 $V_u = 0.00029699$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$

$V_{s,j1} = 314159.265$  is calculated for section web jacket, with:

$d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 589048.623$  is calculated for section flange jacket, with:

$d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$

$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 92890.612$  is calculated for section flange core, with:

$d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), ACI 440) = 372533.843$

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,

where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(,)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$  (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:  $V_s + V_f \leq 836763.965$

$b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$

$V_{Col0} = 995834.294$

$k_{nl} = 1$  (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).

$\gamma = 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.54545$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$   
 $\mu_u = 30.38458$   
 $V_u = 0.00029699$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{sjacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{sjacket} = V_{sj1} + V_{sj2} = 903207.888$   
 $V_{sj1} = 314159.265$  is calculated for section web jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{sj1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.3125$   
 $V_{sj2} = 589048.623$  is calculated for section flange jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{sj2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 0.00$  is calculated for section web core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 92890.612$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(, )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $b_w = 400.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At local axis: 2  
 -----

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjcs

## 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 Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_b/l_d \geq 1$ )

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,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

Bending Moment,  $M = -48804.308$

Shear Force,  $V_2 = 4295.351$

Shear Force,  $V_3 = -63.42516$

Axial Force,  $F = -16978.285$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 0.00$

-Compression:  $A_{sl,c} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1137.257$

-Compression:  $A_{sl,com} = 2208.54$

-Middle:  $A_{sl,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten,jacket} = 829.3805$

-Compression:  $A_{sl,com,jacket} = 1746.726$

-Middle:  $A_{sl,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten,core} = 307.8761$

-Compression:  $A_{sl,com,core} = 461.8141$

-Middle:  $A_{sl,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = u = 0.03882107$   
 $u = y + p = 0.03882107$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00126774$  ((4.29), Biskinis Phd))  
 $M_y = 7.0212E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 769.4787  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4205E+014$   
 $factor = 0.30$   
 $A_g = 440000.00$   
Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.54545$   
 $N = 16978.285$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$   
web width,  $b_w = 400.00$   
flange thickness,  $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 5.2948555E-006$   
with  $f_y = 601.9953$   
 $d = 707.00$   
 $y = 0.19593792$   
 $A = 0.01014894$   
 $B = 0.00445935$   
with  $p_t = 0.0064556$   
 $p_c = 0.00416509$   
 $p_v = 0.00378591$   
 $N = 16978.285$   
 $b = 750.00$   
 $" = 0.06082037$   
 $y_{comp} = 1.5451339E-005$   
with  $f_c' (12.3, (ACI 440)) = 30.48734$   
 $f_c = 30.00$   
 $f_l = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $rc = 40.00$   
 $A_e / A_c = 0.31291181$   
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 25742.96$   
 $y = 0.19514075$   
 $A = 0.01002065$   
 $B = 0.00440616$   
with  $E_s = 200000.00$   
CONFIRMATION:  $y = 0.19593792 < t/d$

Calculation of ratio  $I_b / I_d$

Adequate Lap Length:  $I_b / I_d \geq 1$



- Calculation of  $p$  -

From table 10-8:  $p = 0.03755332$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/l_d \geq 1$

shear control ratio  $V_yE/V_{ColOE} = 1.21726$

$d = d_{\text{external}} = 707.00$

$s = s_{\text{external}} = 0.00$

-  $t = s_1 + s_2 + 2 \cdot t_f/bw \cdot (f_{fe}/f_s) = 0.0064556$

jacket:  $s_1 = A_{v1} \cdot L_{\text{stir1}}/(s_1 \cdot A_g) = 0.00367709$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{\text{stir1}} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} \cdot L_{\text{stir2}}/(s_2 \cdot A_g) = 0.00067082$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{\text{stir2}} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2 \cdot t_f/bw \cdot (f_{fe}/f_s)$  is implemented to account for FRP contribution

where  $f = 2 \cdot t_f/bw$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe}/f_s$  normalises  $f$  to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 16978.285$

$A_g = 440000.00$

$f_{cE} = (f_{c\_jacket} \cdot A_{\text{jacket}} + f_{c\_core} \cdot A_{\text{core}})/\text{section\_area} = 27.54545$

$f_{yE} = (f_{y\_ext\_Long\_Reinf} \cdot A_{\text{ext\_Long\_Reinf}} + f_{y\_int\_Long\_Reinf} \cdot A_{\text{int\_Long\_Reinf}})/A_{\text{Tot\_Long\_Rein}} = 601.9953$

$f_{yE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2)/(s_1 + s_2) = 609.5715$

$p_l = A_{\text{Tot\_Long\_Rein}}/(b \cdot d) = 0.01009575$

$b = 750.00$

$d = 707.00$

$f_{cE} = 27.54545$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 15

column C1, Floor 1

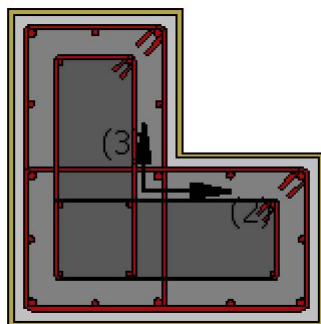
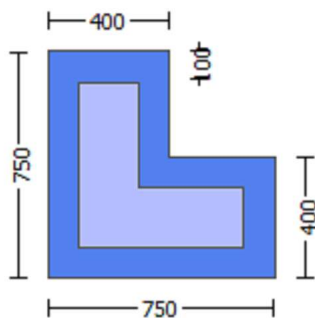
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjlcs

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 Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$

New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_c = f_{cm} = 30.00$

New material: Steel Strength,  $f_s = f_{sm} = 625.00$

Existing Column

Existing material: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )

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°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

#### Stepwise Properties

EDGE -A-  
Bending Moment, Ma = -140135.355  
Shear Force, Va = 63.42516  
EDGE -B-  
Bending Moment, Mb = -48804.308  
Shear Force, Vb = -63.42516  
BOTH EDGES  
Axial Force, F = -16978.285  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 5353.274  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 1137.257  
-Compression: Asl,com = 2208.54  
-Middle: Asl,mid = 2007.478  
Mean Diameter of Tension Reinforcement, DbL,ten = 16.80

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity VR = \*Vn = 943705.324  
Vn ((10.3), ASCE 41-17) = knl\*VColO = 943705.324  
VCol = 943705.324  
knl = 1.00  
displacement\_ductility\_demand = 1.3412514E-005

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 = 18.36364, but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
M/Vd = 2.00  
Mu = 48804.308  
Vu = 63.42516  
d = 0.8\*h = 600.00  
Nu = 16978.285  
Ag = 300000.00  
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 796878.80  
where:  
Vs,jacket = Vs,j1 + Vs,j2 = 722566.31  
Vs,j1 = 471238.898 is calculated for section web jacket, with:  
d = 600.00  
Av = 157079.633  
fy = 500.00  
s = 100.00  
Vs,j1 is multiplied by Col,j1 = 1.00  
s/d = 0.16666667  
Vs,j2 = 251327.412 is calculated for section flange jacket, with:  
d = 320.00  
Av = 157079.633  
fy = 500.00  
s = 100.00  
Vs,j2 is multiplied by Col,j2 = 1.00  
s/d = 0.3125  
Vs,core = Vs,c1 + Vs,c2 = 74312.489  
Vs,c1 = 74312.489 is calculated for section web core, with:  
d = 440.00  
Av = 100530.965

$f_y = 420.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 420.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$   
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 $\ln(11.3) \sin + \cos$  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,  $tf1 = NL \cdot t / \text{NoDir} = 1.016$   
 $dfv = d$  (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:  $V_s + V_f \leq 683214.917$   
 $bw = 400.00$

displacement\_ductility\_demand is calculated as  $\delta / y$

- Calculation of  $\delta / y$  for END B -  
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation  $\theta = 1.7003645E-008$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00126774$  ((4.29), Biskinis Phd))  
 $M_y = 7.0212E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 769.4787  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.4205E+014$   
 $\text{factor} = 0.30$   
 $A_g = 440000.00$   
 Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.54545$   
 $N = 16978.285$   
 $E_c \cdot I_g = E_{c,\text{jacket}} \cdot I_{g,\text{jacket}} + E_{c,\text{core}} \cdot I_{g,\text{core}} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$   
 web width,  $bw = 400.00$   
 flange thickness,  $t = 400.00$

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 5.2948555E-006$   
 with  $f_y = 601.9953$   
 $d = 707.00$   
 $y = 0.19593792$   
 $A = 0.01014894$   
 $B = 0.00445935$   
 with  $pt = 0.00214476$   
 $pc = 0.00416509$

$p_v = 0.00378591$   
 $N = 16978.285$   
 $b = 750.00$   
 $" = 0.06082037$   
 $y_{comp} = 1.5451339E-005$   
 with  $f_c^* (12.3, (ACI 440)) = 30.48734$   
 $f_c = 30.00$   
 $f_l = 0.49678681$   
 $b = b_{max} = 750.00$   
 $h = h_{max} = 750.00$   
 $A_g = 0.44$   
 $g = p_t + p_c + p_v = 0.01009575$   
 $rc = 40.00$   
 $A_e/A_c = 0.31291181$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 25742.96$   
 $y = 0.19514075$   
 $A = 0.01002065$   
 $B = 0.00440616$   
 with  $E_s = 200000.00$   
 CONFIRMATION:  $y = 0.19593792 < t/d$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 16

column C1, Floor 1

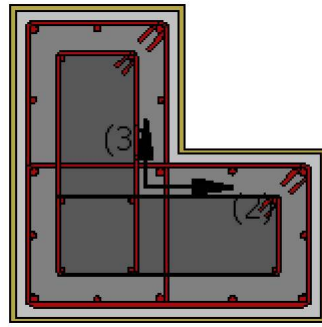
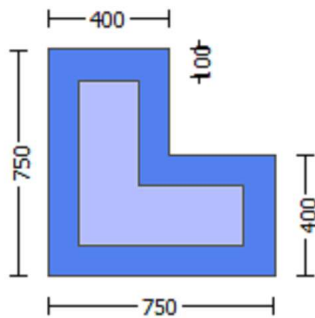
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlcs

Constant Properties

Knowledge Factor,  $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$

Concrete Elasticity,  $E_c = 25742.96$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$

Concrete Elasticity,  $E_c = 23025.204$

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,  $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Max Height,  $H_{max} = 750.00$

Min Height,  $H_{min} = 400.00$

Max Width,  $W_{max} = 750.00$

Min Width,  $W_{min} = 400.00$

Jacket Thickness,  $t_j = 100.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.27105

Element Length,  $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_o/l_{ou,min} \geq 1$ )

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,  $b_i = 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = -0.000297$

EDGE -B-

Shear Force,  $V_b = 0.000297$

BOTH EDGES

Axial Force,  $F = -16273.615$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1137.257$

-Compression:  $As_{c,com} = 2208.54$

-Middle:  $As_{mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.21726$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$  with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.8183E+009$

$\mu_{1+} = 1.5436E+009$ , 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

$\mu_{1-} = 1.8183E+009$ , 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.8183E+009$

$\mu_{2+} = 1.5436E+009$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 1.8183E+009$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $\mu_{1+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 5.2115571E-005$

$M_u = 1.5436E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00102302$

$N = 16273.615$

$f_c = 30.00$

$\phi$  (5A.5, TBDY) = 0.002

Final value of  $\phi \mu$ :  $\phi \mu^* = \text{shear\_factor} * \text{Max}(\phi \mu, \phi c) = 0.01596533$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi \mu = 0.01596533$

we ((5.4c), TBDY) =  $a_s e^* \cdot \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$

where  $f = a_f * \rho_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00508$   
 $bw = 400.00$   
effective stress from (A.35),  $ff,e = 860.3348$

$f_y = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35),  $ff,e = 860.3348$

$R = 40.00$

Effective FRP thickness,  $tf = NL \cdot t \cdot \cos(b1) = 1.016$

$f_u, f = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$

$ase ((5.4d), TBDY) = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.45746528$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d)) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.31295$

$psh1 ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$psh2 ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$



```

fce = 30.00
From ((5.A5), TBDY), TBDY: cc = 0.00471045
c = confinement factor = 1.27105
y1 = 0.0025
sh1 = 0.008
ft1 = 896.8923
fy1 = 747.4102
su1 = 0.032
using (30) in Biskinis/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 = 1.00
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 747.4102
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 906.1344
fy2 = 755.112
su2 = 0.032
using (30) in Biskinis/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 = 1.00
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 755.112
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.
with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

```

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->  
 $\mu_u(4.8) = 0.13151351$   
 $M_u = M_{Rc}(4.15) = 1.5436E+009$   
 $u = \mu_u(4.1) = 5.2115571E-005$

Calculation of ratio  $I_b/I_d$

Adequate Lap Length:  $I_b/I_d \geq 1$

Calculation of  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu_u = 6.7707597E-005$   
 $M_u = 1.8183E+009$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00191815$   
 $N = 16273.615$

$f_c = 30.00$   
 $\alpha_{co}(5A.5, TBDY) = 0.002$

Final value of  $\mu_{cu}$ :  $\mu_{cu}^* = \text{shear\_factor} * \text{Max}(\mu_{cu}, \alpha_{co}) = 0.01596533$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_{cu} = 0.01596533$

$\mu_{we}((5.4c), TBDY) = \alpha_{se} * \text{sh,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$

where  $f = \alpha_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$f_y = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{fe} = 860.3348$

$R = 40.00$

Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

$\alpha_{se}((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int})/A_{sec} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)  
 "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and  
 is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and  
 is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length  
 equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization  
 of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)  
 "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and  
 is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and  
 is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length  
 equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.31295$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1 ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$   
 $s1 = 100.00$   
 $s2 = 250.00$   
 $f_{ywe1} = 781.25$   
 $f_{ywe2} = 656.25$   
 $f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$

$y1 = 0.0025$   
 $sh1 = 0.008$   
 $ft1 = 906.1344$   
 $fy1 = 755.112$   
 $su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$

$l_o/l_{ou,min} = l_b/l_d = 1.00$   
 $su1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 755.112$

with  $Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.0025$   
 $sh2 = 0.008$   
 $ft2 = 896.8923$   
 $fy2 = 747.4102$

```

su2 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 747.4102
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
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 = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 5.2115571E-005

Mu = 1.5436E+009

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\alpha (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \alpha = 0.01596533$$

$$\alpha_e ((5.4c), \text{TB DY}) = \alpha_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$$

where  $f = \alpha^* p f^* f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0465966$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p f = 2 t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$f_y = 0.0465966$$

Expression ((15B.6), TB DY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p f = 2 t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_u, f = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$\alpha_e ((5.4d), \text{TB DY}) = (\alpha_e 1 * A_{\text{ext}} + \alpha_e 2 * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\alpha_e 1 = \text{Max}(((A_{\text{conf}, \max 1} - A_{\text{noConf1}}) / A_{\text{conf}, \max 1}) * (A_{\text{conf}, \min 1} / A_{\text{conf}, \max 1}), 0) = 0.45746528$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf}, \min}$  and  $A_{\text{conf}, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf}, \max 1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf}, \min 1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{\text{conf}, \max 1}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$\alpha_e 2 (> \alpha_e 1) = \text{Max}(((A_{\text{conf}, \max 2} - A_{\text{noConf2}}) / A_{\text{conf}, \max 2}) * (A_{\text{conf}, \min 2} / A_{\text{conf}, \max 2}), 0) = 0.45746528$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf}, \min}$  and  $A_{\text{conf}, \max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf}, \max 2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{\text{conf}, \min 2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{\text{conf}, \max 2}$  by a length equal to half the clear spacing between internal hoops.

$A_{\text{noConf2}} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{\text{sh}, \min} * f_{ywe} = \text{Min}(p_{\text{sh}, x} * f_{ywe}, p_{\text{sh}, y} * f_{ywe}) = 3.31295$$

$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
 $psh1 ((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 (5.4d) = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.31295$   
 $psh1 ((5.4d), TBDY) = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$   
 $Lstir1 \text{ (Length of stirrups along X)} = 2060.00$   
 $Astir1 \text{ (stirrups area)} = 78.53982$   
 $psh2 ((5.4d), TBDY) = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
 $Lstir2 \text{ (Length of stirrups along X)} = 1468.00$   
 $Astir2 \text{ (stirrups area)} = 50.26548$

$Asec = 440000.00$   
 $s1 = 100.00$   
 $s2 = 250.00$   
 $fywe1 = 781.25$   
 $fywe2 = 656.25$   
 $fce = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$

$y1 = 0.0025$   
 $sh1 = 0.008$   
 $ft1 = 896.8923$   
 $fy1 = 747.4102$   
 $su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou,min = lb/ld = 1.00$

$su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 747.4102$

with  $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$

$y2 = 0.0025$   
 $sh2 = 0.008$   
 $ft2 = 906.1344$   
 $fy2 = 755.112$   
 $su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$

$lo/lou,min = lb/lb,min = 1.00$

$su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$

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.

$y2, sh2, ft2, fy2$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 755.112$

with  $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$

$yv = 0.0025$   
 $shv = 0.008$   
 $ftv = 902.993$   
 $fyv = 752.4941$   
 $suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$

$lo/lou,min = lb/ld = 1.00$

$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$

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  $e_{suv\_nominal}$  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  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{sl,mid,jacket} + f_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 752.4941$

with  $E_{sv} = (E_{s,jacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$

$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.05343374$

$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.10483702$

$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.09496245$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} \text{ (5A.2, TBDY)} = 38.13135$

$cc \text{ (5A.5, TBDY)} = 0.00471045$

$c = \text{confinement factor} = 1.27105$

$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.06065386$

$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.11900291$

$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.10779406$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied

---->

$v < v_{s,c}$  - RHS eq.(4.5) is satisfied

---->

$su \text{ (4.8)} = 0.13151351$

$Mu = MRc \text{ (4.15)} = 1.5436E+009$

$u = su \text{ (4.1)} = 5.2115571E-005$

Calculation of ratio  $lb/ld$

Adequate Lap Length:  $lb/ld \geq 1$

Calculation of  $Mu_2$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 6.7707597E-005$

$Mu = 1.8183E+009$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00191815$

$N = 16273.615$

$f_c = 30.00$

$co \text{ (5A.5, TBDY)} = 0.002$

Final value of  $cu$ :  $cu^* = \text{shear\_factor} \cdot \text{Max}(cu, cc) = 0.01596533$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $cu = 0.01596533$

$w_e \text{ ((5.4c), TBDY)} = a_{se} \cdot sh_{min} \cdot fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.09711526$

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)

$fx = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{f,e} = 860.3348$

$f_y = 0.0465966$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.31984848$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35),  $f_{f,e} = 860.3348$

$R = 40.00$

Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_u, f = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$

$a_{se} ((5.4d), TBDY) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int})/A_{sec} = 0.45746528$

$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) \cdot (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) \cdot (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 3.31295$

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 3.31295$

$p_{sh1} ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2} (5.4d) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{s2} \cdot F_{ywe2} = 3.31295$

$p_{sh1} ((5.4d), TBDY) = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$p_{sh2} ((5.4d), TBDY) = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$



```

c = confinement factor = 1.27105
y1 = 0.0025
sh1 = 0.008
ft1 = 906.1344
fy1 = 755.112
su1 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 755.112
with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00
y2 = 0.0025
sh2 = 0.008
ft2 = 896.8923
fy2 = 747.4102
su2 = 0.032
using (30) in Biskinis/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 = 1.00
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 = 747.4102
with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00
yv = 0.0025
shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
using (30) in Biskinis/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 = 1.00
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 = 752.4941
with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1965694
2 = Asl,com/(b*d)*(fs2/fc) = 0.10018826
v = Asl,mid/(b*d)*(fsv/fc) = 0.1780546
and confined core properties:
b = 340.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied

```

```

--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005
-----

Calculation of ratio lb/ld
-----

Adequate Lap Length: lb/ld >= 1
-----
-----
-----

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 995834.294
-----

Calculation of Shear Strength at edge 1, Vr1 = 995834.294
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 995834.294
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*Areajacket + fc'core*Areacore)/Areasection = 27.54545, but fc'0.5 <=
8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 30.3689
Vu = 0.000297
d = 0.8*h = 600.00
Nu = 16273.615
Ag = 300000.00
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 996098.499
where:
Vs,jacket = Vs,j1 + Vs,j2 = 903207.888
Vs,j1 = 589048.623 is calculated for section web jacket, with:
d = 600.00
Av = 157079.633
fy = 625.00
s = 100.00
Vs,j1 is multiplied by Col,j1 = 1.00
s/d = 0.16666667
Vs,j2 = 314159.265 is calculated for section flange jacket, with:
d = 320.00
Av = 157079.633
fy = 625.00
s = 100.00
Vs,j2 is multiplied by Col,j2 = 1.00
s/d = 0.3125
Vs,core = Vs,c1 + Vs,c2 = 92890.612
Vs,c1 = 92890.612 is calculated for section web core, with:
d = 440.00
Av = 100530.965
fy = 525.00
s = 250.00
Vs,c1 is multiplied by Col,c1 = 1.00
s/d = 0.56818182
Vs,c2 = 0.00 is calculated for section flange core, with:
d = 160.00
Av = 100530.965
fy = 525.00
s = 250.00
Vs,c2 is multiplied by Col,c2 = 0.00
s/d = 1.5625
Vf ((11-3)-(11.4), ACI 440) = 372533.843

```

$f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , 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,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 707.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $b_w = 400.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$   
 $V_{r2} = V_{Col}((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 995834.294$   
 $k_{nl} = 1$  (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).

$f_c = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.54545$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 30.36921$   
 $\nu_u = 0.000297$   
 $d = 0.8 \cdot h = 600.00$   
 $N_u = 16273.615$   
 $A_g = 300000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$   
 where:  
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$   
 $V_{s,j1} = 589048.623$  is calculated for section web jacket, with:  
 $d = 600.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$   
 $s/d = 0.16666667$   
 $V_{s,j2} = 314159.265$  is calculated for section flange jacket, with:  
 $d = 320.00$   
 $A_v = 157079.633$   
 $f_y = 625.00$   
 $s = 100.00$   
 $V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$   
 $s/d = 0.3125$   
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$   
 $V_{s,c1} = 92890.612$  is calculated for section web core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 1.00$   
 $s/d = 0.56818182$   
 $V_{s,c2} = 0.00$  is calculated for section flange core, with:  
 $d = 160.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 0.00$   
 $s/d = 1.5625$

$V_f((11-3)-(11.4), \text{ACI 440}) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$   
 $df_v = d$  (figure 11.2, ACI 440) = 707.00  
 $ffe((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$   
 $bw = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjlc

#### Constant Properties

Knowledge Factor,  $\phi = 1.00$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
 Concrete Elasticity,  $E_c = 23025.204$   
 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,  $f_s = 1.25 \cdot f_{sm} = 781.25$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 656.25$   
 #####  
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.27105  
 Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Adequate Lap Length ( $l_o/l_{ou, \min} \geq 1$ )

#### FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $N_{oDir} = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -0.00029699$

EDGE -B-

Shear Force,  $V_b = 0.00029699$

BOTH EDGES

Axial Force,  $F = -16273.615$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1137.257$

-Compression:  $As_{l,com} = 2208.54$

-Middle:  $As_{l,mid} = 2007.478$

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.21726$

Member Controlled by Shear ( $V_e/V_r > 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.2122E+006$  with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.8183E+009$

$\mu_{u1+} = 1.5436E+009$ , 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

$\mu_{u1-} = 1.8183E+009$ , 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

$M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.8183E+009$

$\mu_{u2+} = 1.5436E+009$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u2-} = 1.8183E+009$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

#### Calculation of $\mu_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 5.2115571E-005$

$\mu_u = 1.5436E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00102302$

$N = 16273.615$

$f_c = 30.00$

$\phi_{co} (5A.5, \text{TBDY}) = 0.002$

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01596533$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.01596533$   
 $w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$   
 where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

---


$$f_x = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 860.3348$$

---


$$f_y = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 860.3348$$

---


$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.31295$$

---


$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.31295$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00367709$$

$$L_{stir1} (\text{Length of stirrups along Y}) = 2060.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} (5.4d) = L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00067082$$

$$L_{stir2} (\text{Length of stirrups along Y}) = 1468.00$$

$$A_{stir2} (\text{stirrups area}) = 50.26548$$

---


$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.31295$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00367709$$

$$L_{stir1} (\text{Length of stirrups along X}) = 2060.00$$

Astir1 (stirrups area) = 78.53982  
 $psh2 ((5.4d), TBDY) = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$   
 Lstir2 (Length of stirrups along X) = 1468.00  
 Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 896.8923

fy1 = 747.4102

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 747.4102

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 906.1344

fy2 = 755.112

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 755.112

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025

shv = 0.008

ftv = 902.993

fyv = 752.4941

suv = 0.032

using (30) in Biskinis/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 = 1.00

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  $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 752.4941

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.05343374

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.10483702

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.09496245

and confined core properties:

b = 690.00

$d = 677.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.06065386$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11900291$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.10779406$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is not satisfied  
 --->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied  
 --->

$s_u (4.8) = 0.13151351$   
 $M_u = M_{Rc} (4.15) = 1.5436E+009$   
 $u = s_u (4.1) = 5.2115571E-005$

Calculation of ratio  $l_b/d$

Adequate Lap Length:  $l_b/d \geq 1$

Calculation of  $M_{u1}$ -

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 6.7707597E-005$   
 $M_u = 1.8183E+009$

with full section properties:

$b = 400.00$   
 $d = 707.00$   
 $d' = 43.00$   
 $v = 0.00191815$   
 $N = 16273.615$   
 $f_c = 30.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01596533$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01596533$   
 $w_e ((5.4c), TBDY) = a_{se} * sh_{min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.09711526$   
 where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.0465966$   
 Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$   
 $a_f = 0.31984848$   
 with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$   
 $b_{max} = 750.00$   
 $h_{max} = 750.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{fe} = 860.3348$

$f_y = 0.0465966$   
 Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$   
 $a_f = 0.31984848$   
 with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$   
 $b_{max} = 750.00$   
 $h_{max} = 750.00$   
 From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00508$   
 $b_w = 400.00$   
 effective stress from (A.35),  $f_{fe} = 860.3348$



$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_f = 0.015$$

$$ase((5.4d), \text{TB DY}) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.45746528$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.31295$$

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$$

$$psh1((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$L_{stir1}$  (Length of stirrups along Y) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$$psh2(5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$L_{stir2}$  (Length of stirrups along Y) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$$

$$psh1((5.4d), \text{TB DY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$L_{stir1}$  (Length of stirrups along X) = 2060.00

$A_{stir1}$  (stirrups area) = 78.53982

$$psh2((5.4d), \text{TB DY}) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$L_{stir2}$  (Length of stirrups along X) = 1468.00

$A_{stir2}$  (stirrups area) = 50.26548

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 781.25$$

$$f_{ywe2} = 656.25$$

$$f_{ce} = 30.00$$

From ((5.A5), TB DY), TB DY:  $cc = 0.00471045$

$c$  = confinement factor = 1.27105

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 906.1344$$

$$fy1 = 755.112$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

$$su1 = 0.4 * esu1_{nominal}((5.5), \text{TB DY}) = 0.032$$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs1 = (fs\_jacket \cdot Asl\_ten\_jacket + fs\_core \cdot Asl\_ten\_core) / Asl\_ten = 755.112$   
with  $Es1 = (Es\_jacket \cdot Asl\_ten\_jacket + Es\_core \cdot Asl\_ten\_core) / Asl\_ten = 200000.00$   
 $y2 = 0.0025$   
 $sh2 = 0.008$   
 $ft2 = 896.8923$   
 $fy2 = 747.4102$   
 $su2 = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/lb, min = 1.00$   
 $su2 = 0.4 \cdot esu2\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fs2 = (fs\_jacket \cdot Asl\_com\_jacket + fs\_core \cdot Asl\_com\_core) / Asl\_com = 747.4102$   
with  $Es2 = (Es\_jacket \cdot Asl\_com\_jacket + Es\_core \cdot Asl\_com\_core) / Asl\_com = 200000.00$   
 $yv = 0.0025$   
 $shv = 0.008$   
 $ftv = 902.993$   
 $fyv = 752.4941$   
 $suv = 0.032$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou, min = lb/ld = 1.00$   
 $suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
with  $fsv = (fs\_jacket \cdot Asl\_mid\_jacket + fs\_mid \cdot Asl\_mid\_core) / Asl\_mid = 752.4941$   
with  $Es_v = (Es\_jacket \cdot Asl\_mid\_jacket + Es\_mid \cdot Asl\_mid\_core) / Asl\_mid = 200000.00$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.1965694$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.10018826$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.1780546$   
and confined core properties:  
 $b = 340.00$   
 $d = 677.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 38.13135$   
 $cc (5A.5, TBDY) = 0.00471045$   
 $c = \text{confinement factor} = 1.27105$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs1 / fc) = 0.2415059$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs2 / fc) = 0.12309166$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.21875854$   
Case/Assumption: Unconfined full section - Steel rupture  
'satisfies Eq. (4.3)  
--->  
 $v < vs, y2$  - LHS eq.(4.5) is not satisfied  
--->  
 $v < vs, c$  - RHS eq.(4.5) is satisfied  
--->  
 $su (4.8) = 0.3315127$   
 $Mu = MRc (4.15) = 1.8183E+009$   
 $u = su (4.1) = 6.7707597E-005$

Calculation of ratio  $lb/ld$

Adequate Lap Length:  $lb/ld \geq 1$

## Calculation of $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 5.2115571\text{E-}005$$

$$\mu_{\mu} = 1.5436\text{E+}009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00102302$$

$$N = 16273.615$$

$$f_c = 30.00$$

$$\alpha_{\text{co}} (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_{\text{cu}}: \mu_{\text{cu}}^* = \text{shear\_factor} * \text{Max}(\mu_{\text{cu}}, \alpha_{\text{co}}) = 0.01596533$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{\text{cu}} = 0.01596533$$

$$\mu_{\text{we}} ((5.4c), \text{TBDY}) = \alpha_{\text{se}} * \mu_{\text{sh,min}} * f_{y\text{we}} / f_{\text{ce}} + \text{Min}(\mu_{\text{fx}}, \mu_{\text{fy}}) = 0.09711526$$

where  $\mu_{\text{f}} = \alpha_{\text{f}} * \mu_{\text{p}} * f_{\text{fe}} / f_{\text{ce}}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{\text{fx}} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_{\text{f}} = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_{\text{f}} = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{\text{pf}} = 2t_{\text{f}} / b_{\text{w}} = 0.00508$$

$$b_{\text{w}} = 400.00$$

$$\text{effective stress from (A.35), } f_{\text{fe}} = 860.3348$$

$$\mu_{\text{fy}} = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $\alpha_{\text{f}} = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_{\text{f}} = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{\text{pf}} = 2t_{\text{f}} / b_{\text{w}} = 0.00508$$

$$b_{\text{w}} = 400.00$$

$$\text{effective stress from (A.35), } f_{\text{fe}} = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_{\text{f}} = N L * t * \text{Cos}(\beta_1) = 1.016$$

$$f_{\text{u,f}} = 1055.00$$

$$E_{\text{f}} = 64828.00$$

$$\mu_{\text{u,f}} = 0.015$$

$$\alpha_{\text{se}} ((5.4d), \text{TBDY}) = (\alpha_{\text{se1}} * A_{\text{ext}} + \alpha_{\text{se2}} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\alpha_{\text{se1}} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max1}}$  by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$  is the unconfined external core area which is equal to  $b^2/6$  as defined at (A.2).

$$\alpha_{\text{se2}} (>= \alpha_{\text{se1}}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of  $A_{\text{noConf}}$ ,  $A_{\text{conf,min}}$  and  $A_{\text{conf,max}}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.31295$

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along Y) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2$  (5.4d) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along Y) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.31295$   
 $psh1$  ((5.4d), TBDY) =  $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$   
 $L_{stir1}$  (Length of stirrups along X) = 2060.00  
 $A_{stir1}$  (stirrups area) = 78.53982  
 $psh2$  ((5.4d), TBDY) =  $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$   
 $L_{stir2}$  (Length of stirrups along X) = 1468.00  
 $A_{stir2}$  (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 781.25$

$f_{ywe2} = 656.25$

$f_{ce} = 30.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00471045$

$c$  = confinement factor = 1.27105

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 896.8923$

$fy1 = 747.4102$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lo_{min} = lb/ld = 1.00$

$su1 = 0.4 * esu1_{nominal}$  ((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  $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 747.4102$

with  $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 906.1344$

$fy2 = 755.112$

$su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{min} = lb/lb_{min} = 1.00$

$su2 = 0.4 * esu2_{nominal}$  ((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  $fs2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 755.112$

with  $Es2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$

$yv = 0.0025$

```

shv = 0.008
ftv = 902.993
fyv = 752.4941
suv = 0.032
    using (30) in Biskinis/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 = 1.00
    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 = 752.4941
    with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.05343374
    2 = Asl,com/(b*d)*(fs2/fc) = 0.10483702
    v = Asl,mid/(b*d)*(fsv/fc) = 0.09496245
and confined core properties:
b = 690.00
d = 677.00
d' = 13.00
fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
    c = confinement factor = 1.27105
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.06065386
    2 = Asl,com/(b*d)*(fs2/fc) = 0.11900291
    v = Asl,mid/(b*d)*(fsv/fc) = 0.10779406
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is not satisfied
---->
v < vs,c - RHS eq.(4.5) is satisfied
---->
su (4.8) = 0.13151351
Mu = MRc (4.15) = 1.5436E+009
u = su (4.1) = 5.2115571E-005

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 6.7707597E-005  
Mu = 1.8183E+009

with full section properties:

```

b = 400.00
d = 707.00
d' = 43.00
v = 0.00191815
    N = 16273.615
fc = 30.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01596533
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01596533
    ve ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.09711526

```

where  $f = af \cdot pf \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.31984848$$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff_e = 860.3348$$

$$f_y = 0.0465966$$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.31984848$$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

$$\text{effective stress from (A.35), } ff_e = 860.3348$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL \cdot t \cdot \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase_1 \cdot A_{ext} + ase_2 \cdot A_{int})/A_{sec} = 0.45746528$$

$$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) \cdot (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max1}$  by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$  is the unconfined external core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) \cdot (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

The definitions of  $A_{noConf}$ ,  $A_{conf,min}$  and  $A_{conf,max}$  are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max2}$  by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$  is the unconfined internal core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{,min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.31295$$

$$psh_x \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 3.31295$$

$$psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh_2 \text{ (5.4d)} = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y \cdot F_{ywe} = psh_1 \cdot F_{ywe1} + ps_2 \cdot F_{ywe2} = 3.31295$$

$$psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s_1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh_2 \text{ ((5.4d), TBDY)} = L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s_2) = 0.00067082$$

Lstir2 (Length of stirrups along X) = 1468.00  
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 781.25

fywe2 = 656.25

fce = 30.00

From ((5.A5), TBDY), TBDY: cc = 0.00471045

c = confinement factor = 1.27105

y1 = 0.0025

sh1 = 0.008

ft1 = 906.1344

fy1 = 755.112

su1 = 0.032

using (30) in Biskinis/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 = 1.00

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 755.112

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 896.8923

fy2 = 747.4102

su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 747.4102

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025

shv = 0.008

ftv = 902.993

fyv = 752.4941

suv = 0.032

using (30) in Biskinis/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 = 1.00

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 752.4941

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.1965694

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.10018826

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.1780546

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00

```

fcc (5A.2, TBDY) = 38.13135
cc (5A.5, TBDY) = 0.00471045
c = confinement factor = 1.27105
1 = Asl,ten/(b*d)*(fs1/fc) = 0.2415059
2 = Asl,com/(b*d)*(fs2/fc) = 0.12309166
v = Asl,mid/(b*d)*(fsv/fc) = 0.21875854
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is not satisfied
---->
v < vs,c - RHS eq.(4.5) is satisfied
---->
su (4.8) = 0.3315127
Mu = MRc (4.15) = 1.8183E+009
u = su (4.1) = 6.7707597E-005

```

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 995834.294$

Calculation of Shear Strength at edge 1,  $V_{r1} = 995834.294$

$V_{r1} = V_{Col} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 995834.294$

$k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_{s+} + f * V_f$ ' where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} * \text{Area}_{jacket} + f'_{c,core} * \text{Area}_{core}) / \text{Area}_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 30.38488$

$V_u = 0.00029699$

$d = 0.8 * h = 600.00$

$N_u = 16273.615$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$

$V_{s,j1} = 314159.265$  is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 625.00$

$s = 100.00$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 589048.623$  is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 625.00$

$s = 100.00$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 525.00$

$s = 250.00$



$V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$

$$s/d = 1.5625$$

$V_{s,c2} = 92890.612$  is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 525.00$$

$$s = 250.00$$

$V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$

$$s/d = 0.56818182$$

$V_f$  ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $\theta$ , 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,  $t_{f1} = N_L * t / \text{NoDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 707.00

$f_{fe}$  ((11-5), ACI 440) = 259.312

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440:  $V_s + V_f \leq 836763.965$

$$b_w = 400.00$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 995834.294$

$V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$

$$V_{Col0} = 995834.294$$

$k_{nl} = 1$  (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:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.54545$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 30.38458$$

$$V_u = 0.00029699$$

$$d = 0.8 * h = 600.00$$

$$N_u = 16273.615$$

$$A_g = 300000.00$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s,jacket} + V_{s,core} = 996098.499$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 903207.888$$

$V_{s,j1} = 314159.265$  is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 625.00$$

$$s = 100.00$$

$V_{s,j1}$  is multiplied by  $Col,j1 = 1.00$

$$s/d = 0.3125$$

$V_{s,j2} = 589048.623$  is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 625.00$$

$$s = 100.00$$

$V_{s,j2}$  is multiplied by  $Col,j2 = 1.00$

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 92890.612$$

$V_{s,c1} = 0.00$  is calculated for section web core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 525.00$$

$s = 250.00$   
 $V_{s,c1}$  is multiplied by  $Col,c1 = 0.00$   
 $s/d = 1.5625$   
 $V_{s,c2} = 92890.612$  is calculated for section flange core, with:  
 $d = 440.00$   
 $A_v = 100530.965$   
 $f_y = 525.00$   
 $s = 250.00$   
 $V_{s,c2}$  is multiplied by  $Col,c2 = 1.00$   
 $s/d = 0.56818182$   
 $V_f((11-3)-(11.4), ACI 440) = 372533.843$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In  $(11.3) \sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , 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) = 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:  $V_s + V_f \leq 836763.965$   
 $bw = 400.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1  
 At local axis: 2  
 -----

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
 At local axis: 3  
 Integration Section: (b)  
 Section Type: rcjics

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 Primary Member: Concrete Strength,  $f_c = f_{cm} = 30.00$   
 New material of Primary Member: Steel Strength,  $f_s = f_{sm} = 625.00$   
 Concrete Elasticity,  $E_c = 25742.96$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$   
 Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$   
 Concrete Elasticity,  $E_c = 23025.204$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 750.00$   
 Min Height,  $H_{min} = 400.00$   
 Max Width,  $W_{max} = 750.00$   
 Min Width,  $W_{min} = 400.00$   
 Jacket Thickness,  $t_j = 100.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Primary Member  
 Smooth Bars  
 Ductile Steel  
 With Detailing for Earthquake Resistance (including stirrups closed at  $135^\circ$ )

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ( $l_b/l_d \geq 1$ )

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions,  $N_{oDir} = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

Bending Moment,  $M = 131013.586$

Shear Force,  $V_2 = 4295.351$

Shear Force,  $V_3 = -63.42516$

Axial Force,  $F = -16978.285$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1137.257$

-Compression:  $As_{l,com} = 2208.54$

-Middle:  $As_{l,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten,jacket} = 829.3805$

-Compression:  $As_{l,com,jacket} = 1746.726$

-Middle:  $As_{l,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten,core} = 307.8761$

-Compression:  $As_{l,com,core} = 461.8141$

-Middle:  $As_{l,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{R} = u = 0.03804758$

$u = y + p = 0.03804758$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00049426$  ((4.29), Biskinis Phd))

$M_y = 7.0212E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 1.4205E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.54545$

$N = 16978.285$

$E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 4.7351E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

Assuming neutral axis within flange ( $y < t/d$ , compression zone rectangular) with:

flange width,  $b = 750.00$

web width,  $b_w = 400.00$

flange thickness,  $t = 400.00$

```

y = Min( y_ten, y_com)
y_ten = 5.2948555E-006
with fy = 601.9953
d = 707.00
y = 0.19593792
A = 0.01014894
B = 0.00445935
with pt = 0.0064556
pc = 0.00416509
pv = 0.00378591
N = 16978.285
b = 750.00
" = 0.06082037
y_comp = 1.5451339E-005
with fc* (12.3, (ACI 440)) = 30.48734
fc = 30.00
fl = 0.49678681
b = bmax = 750.00
h = hmax = 750.00
Ag = 0.44
g = pt + pc + pv = 0.01009575
rc = 40.00
Ae/Ac = 0.31291181
Effective FRP thickness, tf = NL*t*cos(b1) = 1.016
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 25742.96
y = 0.19514075
A = 0.01002065
B = 0.00440616
with Es = 200000.00
CONFIRMATION: y = 0.19593792 < t/d

```

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

- Calculation of p -

From table 10-8: p = 0.03755332

with:

- Columns not controlled by inadequate development or splicing along the clear height because lb/d >= 1

shear control ratio  $V_y E / V_{col} E = 1.21726$

d = d\_external = 707.00

s = s\_external = 0.00

-  $t = s_1 + s_2 + 2*tf/bw*(ffe/fs) = 0.0064556$

jacket:  $s_1 = A_{v1}*L_{stir1}/(s_1*Ag) = 0.00367709$

$A_{v1} = 78.53982$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2}*L_{stir2}/(s_2*Ag) = 0.00067082$

$A_{v2} = 50.26548$ , is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$ , is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term  $2*tf/bw*(ffe/fs)$  is implemented to account for FRP contribution

where  $f = 2*tf/bw$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $ffe/fs$  normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation fs of jacket is used.

NUD = 16978.285

Ag = 440000.00

$f_{cE} = (f_{c\_jacket}*Area\_jacket + f_{c\_core}*Area\_core)/section\_area = 27.54545$

$f_{yE} = (f_{y\_ext\_Long\_Reinf}*Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf}*Area\_int\_Long\_Reinf)/Area\_Tot\_Long\_Rein = 601.9953$

$f_{ytE} = (f_{y\_ext\_Trans\_Reinf} \cdot s1 + f_{y\_int\_Trans\_Reinf} \cdot s2) / (s1 + s2) = 609.5715$   
 $\rho_l = Area\_Tot\_Long\_Rein / (b \cdot d) = 0.01009575$   
 $b = 750.00$   
 $d = 707.00$   
 $f_{cE} = 27.54545$

-----  
End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1  
At local axis: 3  
Integration Section: (b)