

# Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

## Calculation No. 1

column C1, Floor 1

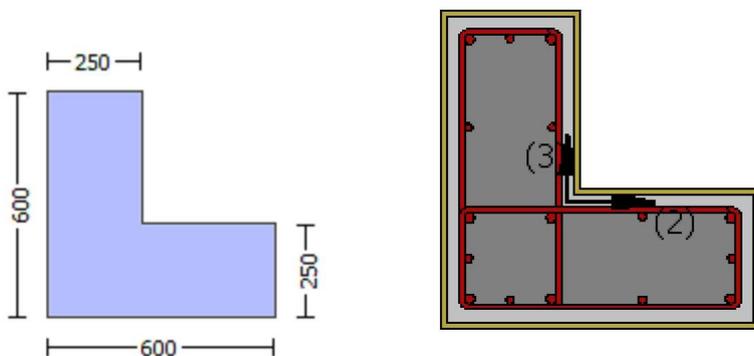
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

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

Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

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Note: Especially for the calculation of  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

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Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

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Stepwise Properties

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EDGE -A-

Bending Moment,  $M_a = -1.2946E+007$

Shear Force,  $V_a = -4259.045$

EDGE -B-

Bending Moment,  $M_b = 164093.879$

Shear Force,  $V_b = 4259.045$

BOTH EDGES

Axial Force,  $F = -9662.362$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression:  $A_{sl,c} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1746.726$

-Compression:  $A_{sl,com} = 829.3805$

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

Mean Diameter of Tension Reinforcement,  $D_{bL,ten} = 17.71429$

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Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 292301.036$

$V_n$  ((10.3), ASCE 41-17) =  $k_n \phi V_{col} = 379611.735$

$V_{col} = 379611.735$

$k_n = 1.00$

displacement\_ductility\_demand = 0.01786943

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NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_s + \phi V_f$ '

where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

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= 1 (normal-weight concrete)

$f_c' = 16.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.2946E+007$   
 $V_u = 4259.045$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 9662.362$   
 $A_g = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 284837.734$   
 where:  
 $V_{s1} = 83775.804$  is calculated for section web, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.75$   
 $V_{s2} = 201061.93$  is calculated for section flange, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.3125$   
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression,  
 where  $\theta$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, \alpha)$ , is implemented for every different fiber orientation  $\alpha_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 557.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 318865.838$   
 $b_w = 250.00$

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  $\theta = 0.00012672$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.0070913$  ((4.29), Biskinis Phd)  
 $M_y = 2.9341E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3039.546  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$   
 $\text{factor} = 0.30$   
 $A_g = 237500.00$   
 $f_c' = 20.00$   
 $N = 9662.362$   
 $E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.0518245E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 277.9106$   
 $d = 557.00$

$y = 0.3842998$   
 $A = 0.02984946$   
 $B = 0.0192317$   
 with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9662.362$   
 $b = 250.00$   
 $" = 0.07719928$   
 $y_{comp} = 8.1947240E-006$   
 with  $fc^* (12.3, (ACI 440)) = 20.42407$   
 $fc = 20.00$   
 $fl = 0.62098351$   
 $b = b_{max} = 600.00$   
 $h = h_{max} = 600.00$   
 $Ag = 237500.00$   
 $g = pt + pc + pv = 0.02959978$   
 $rc = 40.00$   
 $Ae/Ac = 0.21783041$   
 Effective FRP thickness,  $tf = NL*t*\text{Cos}(b1) = 1.016$   
 effective strain from (12.5) and (12.12),  $efe = 0.004$   
 $fu = 0.01$   
 $Ef = 64828.00$   
 $Ec = 21019.039$   
 $y = 0.38318842$   
 $A = 0.02940142$   
 $B = 0.01898202$   
 with  $Es = 200000.00$

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 Calculation of ratio  $lb/l_d$

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 Lap Length:  $l_d/l_{d,min} = 0.3538123$

$lb = 300.00$

$l_d = 847.9072$

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

$= 1$

$db = 18.00$

Mean strength value of all re-bars:  $f_y = 444.44$

$fc' = 20.00$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 150.00$

$n = 16.00$

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 End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

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**Calculation No. 2**

column C1, Floor 1

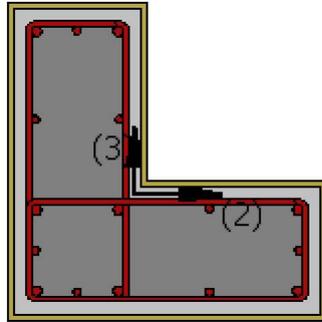
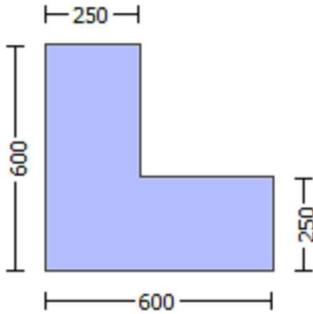
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta$ )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$

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

Consequently:

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

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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

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

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Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions, NoDir = 1  
Fiber orientations, bi: 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

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Stepwise Properties  
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At local axis: 3  
EDGE -A-  
Shear Force, Va = 0.00016213  
EDGE -B-  
Shear Force, Vb = -0.00016213  
BOTH EDGES  
Axial Force, F = -8883.864  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 4121.77  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 1746.726  
-Compression: Asl,com = 829.3805  
-Middle: Asl,mid = 1545.664  
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Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.62612363$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$   
with  
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.9843E+008$   
 $\mu_{1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
which is defined for the static loading combination  
 $\mu_{1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.9843E+008$   
 $\mu_{2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
which is defined for the the static loading combination  
 $\mu_{2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment  
direction which is defined for the the static loading combination

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Calculation of  $\mu_{1+}$   
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Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.1848408E-005$$

$$M_u = 3.9843E+008$$

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with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.0144353$$

$$\mu_e \text{ ((5.4c), TBDY)} = a_s e^* \text{ sh}_{,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35),  $ff,e = 703.4155$

$f_y = 0.06888919$

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

$af = 0.24098246$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35),  $ff,e = 703.4155$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$  ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$p_{sh,y}$  ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c$  = confinement factor = 1.0981

$y1 = 0.00124738$

$sh1 = 0.00431097$

$ft1 = 359.2441$

$fy1 = 299.3701$

$su1 = 0.00446911$

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

$lo/lou,min = lb/ld = 0.28304984$

$su1 = 0.4*esu1_{nominal}$  ((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, ASCE41-17.

with  $f_{s1} = f_s = 299.3701$   
 with  $E_{s1} = E_s = 200000.00$   
 $y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $fy_2 = 299.3701$   
 $su_2 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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, ASCE41-17.  
 with  $f_{s2} = f_s = 299.3701$   
 with  $E_{s2} = E_s = 200000.00$   
 $y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $fy_v = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.28304984$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsy_v = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsy_v = f_{sv}/1.2$ , 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, ASCE41-17.  
 with  $f_{sv} = f_s = 299.3701$   
 with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.18776209$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08915322$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.16614919$

and confined core properties:

$b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$

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

--->  
 $su (4.8) = 0.32281672$   
 $Mu = MR_c (4.15) = 3.9843E+008$   
 $u = su (4.1) = 1.1848408E-005$

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

-----  
 Lap Length:  $l_b/l_d = 0.28304984$   
 $l_b = 300.00$   
 $l_d = 1059.884$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 = 1

db = 18.00

Mean strength value of all re-bars:  $f_y = 555.55$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.61799

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

s = 150.00

n = 16.00

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Calculation of  $\mu_1$ -

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

$\mu = 9.6917274E-006$

$\mu_1 = 2.1970E+008$

-----  
with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

$f_c = 20.00$

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

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.0144353$

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

From (5.4b), TBDY:  $\mu_c = 0.0144353$

where  $\mu_{cc}$  ((5.4c), TBDY) =  $\alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

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

-----  
 $f_x = 0.06888919$

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

$\alpha f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

-----  
 $f_y = 0.06888919$

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

$\alpha f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

-----  
R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{f} = 0.015$

$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00321875$

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

-----  
 $psh_x$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $psh_y$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c = \text{confinement factor} = 1.0981$

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

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

$lo/lo_{min} = lb/ld = 0.28304984$

$su_1 = 0.4 * esu_{1\_nominal}$  ((5.5), TBDY) = 0.032

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

For calculation of  $esu_{1\_nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

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

$lo/lo_{min} = lb/lb_{min} = 0.28304984$

$su_2 = 0.4 * esu_{2\_nominal}$  ((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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_2 = fs = 299.3701$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$su_v = 0.00446911$

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

$lo/lo_{min} = lb/ld = 0.28304984$

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

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

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

For calculation of  $esuv\_nominal$  and  $yv$ ,  $shv,ftv,fyv$ , it is considered characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1,ft1,fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 299.3701$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 21.96205$$

$$cc (5A.5, TBDY) = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.17212448$$

$$Mu = MRc (4.14) = 2.1970E+008$$

$$u = su (4.1) = 9.6917274E-006$$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.28304984$

$$lb = 300.00$$

$$ld = 1059.884$$

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

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars:  $fy = 555.55$

$fc' = 20.00$ , but  $fc^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 2.61799$$

$$Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$$

where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = 150.00$$

$$n = 16.00$$

Calculation of  $Mu2+$

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

$$u = 1.1848408E-005$$

$$Mu = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$\text{we ((5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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

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

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$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$f_{y1} = 299.3701$   
 $s_{u1} = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.28304984$   
 $s_{u1} = 0.4 * e_{s1\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{s1\_nominal} = 0.08$ ,  
 For calculation of  $e_{s1\_nominal}$  and  $y_1, sh_1, ft_1, f_{y1}$ , it is considered  
 characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{s1} = f_s = 299.3701$   
 with  $E_{s1} = E_s = 200000.00$   
 $y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $f_{y2} = 299.3701$   
 $s_{u2} = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$   
 $s_{u2} = 0.4 * e_{s2\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{s2\_nominal} = 0.08$ ,  
 For calculation of  $e_{s2\_nominal}$  and  $y_2, sh_2, ft_2, f_{y2}$ , it is considered  
 characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.  
 $y_2, sh_2, ft_2, f_{y2}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{s2} = f_s = 299.3701$   
 with  $E_{s2} = E_s = 200000.00$   
 $y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $f_{yv} = 299.3701$   
 $s_{uv} = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.28304984$   
 $s_{uv} = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{suv\_nominal} = 0.08$ ,  
 considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $e_{suv\_nominal}$  and  $y_v, sh_v, ft_v, f_{yv}$ , 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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{sv} = f_s = 299.3701$   
 with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.18776209$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08915322$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.16614919$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$   
 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  
 --->  
 $s_u (4.8) = 0.32281672$

$$\begin{aligned} \mu_u &= M/R_c (4.15) = 3.9843E+008 \\ u &= s_u (4.1) = 1.1848408E-005 \end{aligned}$$

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

$$\begin{aligned} \text{Lap Length: } l_b/l_d &= 0.28304984 \\ l_b &= 300.00 \\ l_d &= 1059.884 \end{aligned}$$

Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

$$\begin{aligned} d_b &= 18.00 \\ \text{Mean strength value of all re-bars: } f_y &= 555.55 \\ f_c' &= 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)} \\ t &= 1.00 \\ s &= 0.80 \\ e &= 1.00 \\ c_b &= 25.00 \\ K_{tr} &= 2.61799 \\ A_{tr} &= \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796 \\ &\text{where } A_{tr_x}, A_{tr_y} \text{ are the sum of the area of all stirrup legs along X and Y local axis} \\ s &= 150.00 \\ n &= 16.00 \end{aligned}$$

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

$$\begin{aligned} u &= 9.6917274E-006 \\ \mu_u &= 2.1970E+008 \end{aligned}$$

-----  
with full section properties:

$$\begin{aligned} b &= 600.00 \\ d &= 557.00 \\ d' &= 43.00 \\ v &= 0.00132912 \\ N &= 8883.864 \\ f_c &= 20.00 \\ c_o \text{ (5A.5, TBDY)} &= 0.002 \\ \text{Final value of } c_u: c_u^* &= \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353 \\ &\text{The Shear\_factor is considered equal to 1 (pure moment strength)} \\ \text{From (5.4b), TBDY: } c_u &= 0.0144353 \\ v_e \text{ ((5.4c), TBDY)} &= a_s e * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805 \\ \text{where } f &= a_f * p_f * f_{fe} / f_{ce} \text{ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)} \end{aligned}$$

-----

$$\begin{aligned} f_x &= 0.06888919 \\ \text{Expression ((15B.6), TBDY) is modified as } a_f &= 1 - (\text{Unconfined area}) / (\text{total area}) \\ a_f &= 0.24098246 \\ \text{with Unconfined area} &= ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333 \\ b_{\max} &= 600.00 \\ h_{\max} &= 600.00 \\ \text{From EC8 A.4.4.3(6), } p_f &= 2t_f / b_w = 0.008128 \\ b_w &= 250.00 \\ \text{effective stress from (A.35), } f_{f,e} &= 703.4155 \end{aligned}$$

-----

$$\begin{aligned} f_y &= 0.06888919 \\ \text{Expression ((15B.6), TBDY) is modified as } a_f &= 1 - (\text{Unconfined area}) / (\text{total area}) \\ a_f &= 0.24098246 \\ \text{with Unconfined area} &= ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00 \\ b_{\max} &= 600.00 \\ h_{\max} &= 600.00 \\ \text{From EC8 A.4.4.3(6), } p_f &= 2t_f / b_w = 0.008128 \\ b_w &= 250.00 \\ \text{effective stress from (A.35), } f_{f,e} &= 703.4155 \end{aligned}$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

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$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$$fy_1 = 299.3701$$

$$su_1 = 0.00446911$$

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

$$l_o/l_{o,min} = l_b/l_d = 0.28304984$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 299.3701$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00124738$$

$$sh_2 = 0.00431097$$

$$ft_2 = 359.2441$$

$$fy_2 = 299.3701$$

$$su_2 = 0.00446911$$

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

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,

For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_s2 = f_s = 299.3701$   
 with  $E_s2 = E_s = 200000.00$   
 $y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $fy_v = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.28304984$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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, ASCE41-17.  
 with  $fsv = f_s = 299.3701$   
 with  $Esv = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.03714718$   
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.0782342$   
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.06922883$   
 and confined core properties:  
 $b = 540.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.04362424$   
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.09187529$   
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.08129972$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.17212448$   
 $Mu = MRc (4.14) = 2.1970E+008$   
 $u = su (4.1) = 9.6917274E-006$

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

Lap Length:  $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

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

= 1

$db = 18.00$

Mean strength value of all re-bars:  $fy = 555.55$

$fc' = 20.00$ , but  $fc^{0.5} <= 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = Min(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 150.00$

$n = 16.00$

-----  
 -----  
 -----  
 Calculation of Shear Strength  $V_r = Min(V_{r1}, V_{r2}) = 424229.688$   
 -----

Calculation of Shear Strength at edge 1,  $Vr1 = 424229.688$

$Vr1 = VCol$  ((10.3), ASCE 41-17) =  $knl * VColO$

$VColO = 424229.688$

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

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$fc' = 20.00$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 47.24078$

$Vu = 0.00016213$

$d = 0.8 * h = 480.00$

$Nu = 8883.864$

$Ag = 150000.00$

From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 316483.206$

where:

$Vs1 = 223399.91$  is calculated for section web, with:

$d = 480.00$

$Av = 157079.633$

$fy = 444.44$

$s = 150.00$

$Vs1$  is multiplied by  $Col1 = 1.00$

$s/d = 0.3125$

$Vs2 = 93083.296$  is calculated for section flange, with:

$d = 200.00$

$Av = 157079.633$

$fy = 444.44$

$s = 150.00$

$Vs2$  is multiplied by  $Col2 = 1.00$

$s/d = 0.75$

$Vf$  ((11-3)-(11.4), ACI 440) =  $293495.545$

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

total thickness per orientation,  $tf1 = NL * t / \text{NoDir} = 1.016$

$dfv = d$  (figure 11.2, ACI 440) =  $557.00$

$ffe$  ((11-5), ACI 440) =  $259.312$

$Ef = 64828.00$

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

with  $fu = 0.01$

From (11-11), ACI 440:  $Vs + Vf \leq 356502.845$

$bw = 250.00$

Calculation of Shear Strength at edge 2,  $Vr2 = 424229.688$

$Vr2 = VCol$  ((10.3), ASCE 41-17) =  $knl * VColO$

$VColO = 424229.688$

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

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$fc' = 20.00$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 47.24081$

$Vu = 0.00016213$

$d = 0.8 * h = 480.00$

$Nu = 8883.864$

$Ag = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 223399.91$  is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.3125$

$V_{s2} = 93083.296$  is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.75$

$V_f$  ((11-3)-(11.4), ACI 440) = 293495.545

$f = 0.95$ , for fully-wrapped sections

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

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

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

orientation 1:  $\theta = 45^\circ + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 557.00

$f_{fe}$  ((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:  $V_s + V_f \leq 356502.845$

$b_w = 250.00$

-----  
End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 3

-----  
Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rclcs

Constant Properties

-----  
Knowledge Factor,  $\phi = 0.77$

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

Consequently:

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties

-----  
At local axis: 2

EDGE -A-

Shear Force,  $V_a = 0.00016213$

EDGE -B-

Shear Force,  $V_b = -0.00016213$

BOTH EDGES

Axial Force,  $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{st,ten} = 1746.726$

-Compression:  $A_{st,com} = 829.3805$

-Middle:  $A_{st,mid} = 1545.664$

-----  
-----  
Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.62612363$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with

$M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 3.9843E+008$

$Mu_{1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 3.9843E+008$

$Mu_{2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$Mu_{2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

-----  
Calculation of  $Mu_{1+}$

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

$\phi_u = 1.1848408E-005$

$M_u = 3.9843E+008$

-----  
with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$sh1 = 0.00431097$   
 $ft1 = 359.2441$   
 $fy1 = 299.3701$   
 $su1 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.28304984$   
 $su1 = 0.4*esu1\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE41-17.  
 with  $fs1 = fs = 299.3701$   
 with  $Es1 = Es = 200000.00$   
 $y2 = 0.00124738$   
 $sh2 = 0.00431097$   
 $ft2 = 359.2441$   
 $fy2 = 299.3701$   
 $su2 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/lb,min = 0.28304984$   
 $su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE41-17.  
 with  $fs2 = fs = 299.3701$   
 with  $Es2 = Es = 200000.00$   
 $yv = 0.00124738$   
 $shv = 0.00431097$   
 $ftv = 359.2441$   
 $fyv = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.28304984$   
 $suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE41-17.  
 with  $fsv = fs = 299.3701$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236$   
 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

--->

$$su(4.8) = 0.32281672$$

$$Mu = MRc(4.15) = 3.9843E+008$$

$$u = su(4.1) = 1.1848408E-005$$

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Lap Length: lb/l<sub>d</sub> = 0.28304984

$$lb = 300.00$$

$$ld = 1059.884$$

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

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$$fc' = 20.00, \text{ but } fc'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

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

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

$$u = 9.6917274E-006$$

$$Mu = 2.1970E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$fc = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$\text{we ((5.4c), TBDY) } = a_s e^* \text{ sh, min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 57233.333$$

$$b_{\text{max}} = 600.00$$

$$h_{\text{max}} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 0.00$$

$$b_{\text{max}} = 600.00$$

$$h_{\text{max}} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

bw = 250.00  
effective stress from (A.35),  $f_{f,e} = 703.4155$

R = 40.00  
Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$   
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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along Y) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along X) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

s = 150.00  
 $f_{ywe} = 555.55$   
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$   
c = confinement factor = 1.0981

$y_1 = 0.00124738$   
 $sh_1 = 0.00431097$   
 $ft_1 = 359.2441$   
 $fy_1 = 299.3701$   
 $su_1 = 0.00446911$

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

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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

For calculation of  $esu1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $E_{s1} = E_s = 200000.00$

$y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $fy_2 = 299.3701$   
 $su_2 = 0.00446911$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 \cdot esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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

For calculation of  $esu2_{nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered

characteristic value  $f_{s2} = f_s/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{s2} = f_s = 299.3701$

with  $E_{s2} = E_s = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$s_{uv} = 0.00446911$

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

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

Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/d = 0.28304984$

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

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

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

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{sv} = f_s = 299.3701$

with  $E_{sv} = E_s = 200000.00$

1 =  $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03714718$

2 =  $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0782342$

v =  $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06922883$

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

f<sub>cc</sub> (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

1 =  $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04362424$

2 =  $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09187529$

v =  $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08129972$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

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

---

$\mu_u$  (4.9) = 0.17212448

$\mu_u = M_{Rc}$  (4.14) = 2.1970E+008

u =  $\mu_u$  (4.1) = 9.6917274E-006

-----  
Calculation of ratio  $l_b/d$

-----  
Lap Length:  $l_b/d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

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

= 1

$d_b = 18.00$

Mean strength value of all re-bars:  $f_y = 555.55$

$f'_c = 20.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

s = 150.00

n = 16.00

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-----  
Calculation of  $\mu_{u2+}$

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

$$\mu = 1.1848408E-005$$

$$\mu_u = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.0144353$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = \alpha s_e * \text{sh}_{,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

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

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,\min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00321875$$

$$Lstir (\text{Length of stirrups along } X) = 1460.00$$

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

$$Asec (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y1 = 0.00124738$$

$$sh1 = 0.00431097$$

$$ft1 = 359.2441$$

$$fy1 = 299.3701$$

$$su1 = 0.00446911$$

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

$$lo/lou,min = lb/d = 0.28304984$$

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

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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 299.3701$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00124738$$

$$sh2 = 0.00431097$$

$$ft2 = 359.2441$$

$$fy2 = 299.3701$$

$$su2 = 0.00446911$$

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

$$lo/lou,min = lb/lb,min = 0.28304984$$

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

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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 299.3701$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00124738$$

$$shv = 0.00431097$$

$$ftv = 359.2441$$

$$fyv = 299.3701$$

$$suv = 0.00446911$$

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

$$lo/lou,min = lb/d = 0.28304984$$

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

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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 299.3701$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.18776209$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.08915322$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.16614919$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 21.96205$$

$$cc \text{ (5A.5, TBDY)} = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = \text{Asl,ten}/(b*d)*(fs1/fc) = 0.26111925$$

$$2 = \text{Asl,com}/(b*d)*(fs2/fc) = 0.12398468$$

$$v = \text{Asl,mid}/(b*d)*(fsv/fc) = 0.23106236$$

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

---->

$$su \text{ (4.8)} = 0.32281672$$

$$Mu = MRc \text{ (4.15)} = 3.9843E+008$$

$$u = su \text{ (4.1)} = 1.1848408E-005$$

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

$$\text{Lap Length: } l_b/l_d = 0.28304984$$

$$l_b = 300.00$$

$$l_d = 1059.884$$

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

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 555.55$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

-----  
Calculation of  $Mu_2$ -

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

$$u = 9.6917274E-006$$

$$Mu = 2.1970E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } cu = 0.0144353$$

$$\text{we ((5.4c), TBDY) } = ase * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(fx, fy) = 0.07473805$$

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

$$fx = 0.06888919$$

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

$$af = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.008128$   
 $bw = 250.00$   
effective stress from (A.35),  $ff,e = 703.4155$

$fy = 0.06888919$   
Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
 $af = 0.24098246$   
with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$   
 $b_{max} = 600.00$   
 $h_{max} = 600.00$   
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.008128$   
 $bw = 250.00$   
effective stress from (A.35),  $ff,e = 703.4155$

$R = 40.00$   
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
 $fu,f = 1055.00$   
 $Ef = 64828.00$   
 $u,f = 0.015$   
 $ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.21805635$   
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.  
 $A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.  
 $A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.  
 $A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $bi^2/6$  as defined at (A.2).  
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$   
Expression ((5.4d), TBDY) for  $psh,min$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x$  ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along Y) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

$psh,y$  ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along X) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

$s = 150.00$   
 $fywe = 555.55$   
 $fce = 20.00$   
From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $y1 = 0.00124738$   
 $sh1 = 0.00431097$   
 $ft1 = 359.2441$   
 $fy1 = 299.3701$   
 $su1 = 0.00446911$   
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $lo/lou,min = lb/d = 0.28304984$   
 $su1 = 0.4*esu1\_nominal$  ((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  $\text{Min}(1, 1.25*(lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.  
with  $fs1 = fs = 299.3701$   
with  $Es1 = Es = 200000.00$   
 $y2 = 0.00124738$

$sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $fy_2 = 299.3701$   
 $su_2 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{min} = lb/lb_{min} = 0.28304984$   
 $su_2 = 0.4 * esu_{2\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2\_nominal} = 0.08$ ,  
 For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_2 = fs = 299.3701$   
 with  $Es_2 = Es = 200000.00$   
 $yv = 0.00124738$   
 $shv = 0.00431097$   
 $ftv = 359.2441$   
 $fyv = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{min} = lb/ld = 0.28304984$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 299.3701$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.03714718$   
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.0782342$   
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.06922883$   
 and confined core properties:  
 $b = 540.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.04362424$   
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.09187529$   
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08129972$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

----->

Calculation of ratio  $lb/ld$

----->

Lap Length:  $lb/ld = 0.28304984$   
 $lb = 300.00$   
 $ld = 1059.884$   
 Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 18.00$   
 Mean strength value of all re-bars:  $fy = 555.55$   
 $fc' = 20.00$ , but  $fc^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$

e = 1.00  
cb = 25.00  
Ktr = 2.61799  
Atr = Min(Atr\_x,Atr\_y) = 157.0796  
where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis  
s = 150.00  
n = 16.00

-----  
-----  
-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 424229.688$   
 $V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = knl * V_{Col0}$   
 $V_{Col0} = 424229.688$   
knl = 1 (zero step-static loading)

-----  
NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf'  
where Vf is the contribution of FRPs (11.3), ACI 440).

-----  
= 1 (normal-weight concrete)  
 $fc' = 20.00$ , but  $fc^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
M/Vd = 4.00  
Mu = 47.23669  
Vu = 0.00016213  
d = 0.8\*h = 480.00  
Nu = 8883.864  
Ag = 150000.00  
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 93083.296$  is calculated for section web, with:

d = 200.00  
Av = 157079.633  
fy = 444.44  
s = 150.00

$V_{s1}$  is multiplied by Col1 = 1.00

s/d = 0.75

$V_{s2} = 223399.91$  is calculated for section flange, with:

d = 480.00  
Av = 157079.633  
fy = 444.44  
s = 150.00

$V_{s2}$  is multiplied by Col2 = 1.00

s/d = 0.3125

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

$dfv = d$  (figure 11.2, ACI 440) = 557.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 356502.845$

bw = 250.00

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 424229.688$

$V_{r2} = V_{Col} \text{ ((10.3), ASCE 41-17)} = knl * V_{Col0}$   
 $V_{Col0} = 424229.688$

kn1 = 1 (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf'  
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

fc' = 20.00, but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 47.23667

Vu = 0.00016213

d = 0.8\*h = 480.00

Nu = 8883.864

Ag = 150000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 316483.206

where:

Vs1 = 93083.296 is calculated for section web, with:

d = 200.00

Av = 157079.633

fy = 444.44

s = 150.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.75

Vs2 = 223399.91 is calculated for section flange, with:

d = 480.00

Av = 157079.633

fy = 444.44

s = 150.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.3125

Vf ((11-3)-(11.4), ACI 440) = 293495.545

f = 0.95, for fully-wrapped sections

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

In (11.3)  $\sin^2 + \cos^2$  is replaced with  $(\cot^2 + \csc^2)\sin^2\alpha$  which is more a generalised expression,  
where  $\alpha$  is the angle of the crack direction (see KANEPE).

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

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

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

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

dfv = d (figure 11.2, ACI 440) = 557.00

ffe ((11-5), ACI 440) = 259.312

Ef = 64828.00

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

with fu = 0.01

From (11-11), ACI 440: Vs + Vf <= 356502.845

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1  
At local axis: 2

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00

Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 600.00$   
 Min Height,  $H_{min} = 250.00$   
 Max Width,  $W_{max} = 600.00$   
 Min Width,  $W_{min} = 250.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_b = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $e_{fu} = 0.01$   
 Number of directions,  $NoDir = 1$   
 Fiber orientations,  $b_i = 0.00^\circ$   
 Number of layers,  $NL = 1$   
 Radius of rounding corners,  $R = 40.00$

-----  
 Stepwise Properties

-----  
 Bending Moment,  $M = -320830.403$   
 Shear Force,  $V_2 = -4259.045$   
 Shear Force,  $V_3 = 148.2786$   
 Axial Force,  $F = -9662.362$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $A_{st} = 0.00$   
 -Compression:  $A_{sc} = 4121.77$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $A_{st,ten} = 1746.726$   
 -Compression:  $A_{st,com} = 829.3805$   
 -Middle:  $A_{st,mid} = 1545.664$   
 Mean Diameter of Tension Reinforcement,  $DbL = 17.71429$

-----  
 Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_R = \phi u = 0.00388691$   
 $u = y + p = 0.00504794$

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

-----  
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00504794$  ((4.29), Biskinis Phd))  
 $M_y = 2.9341E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 2163.70  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$   
 $factor = 0.30$   
 $A_g = 237500.00$   
 $f_c' = 20.00$   
 $N = 9662.362$   
 $E_c \cdot I_g = 1.3974E+014$

-----  
 Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 4.0518245\text{E}-006$   
 with  $((10.1), \text{ASCE } 41-17) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 277.9106$   
 $d = 557.00$   
 $y = 0.3842998$   
 $A = 0.02984946$   
 $B = 0.0192317$   
 with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9662.362$   
 $b = 250.00$   
 $" = 0.07719928$   
 $y_{\text{comp}} = 8.1947240\text{E}-006$   
 with  $fc' (12.3, \text{ACI } 440) = 20.42407$   
 $fc = 20.00$   
 $fl = 0.62098351$   
 $b = b_{\text{max}} = 600.00$   
 $h = h_{\text{max}} = 600.00$   
 $Ag = 237500.00$   
 $g = pt + pc + pv = 0.02959978$   
 $rc = 40.00$   
 $Ae/Ac = 0.21783041$   
 Effective FRP thickness,  $tf = NL \cdot t \cdot \text{Cos}(b1) = 1.016$   
 effective strain from (12.5) and (12.12),  $efe = 0.004$   
 $fu = 0.01$   
 $Ef = 64828.00$   
 $Ec = 21019.039$   
 $y = 0.38318842$   
 $A = 0.02940142$   
 $B = 0.01898202$   
 with  $Es = 200000.00$

-----  
 -----  
 Calculation of ratio  $l_b/d$   
 -----

Lap Length:  $l_d/d, \text{min} = 0.3538123$   
 $l_b = 300.00$   
 $l_d = 847.9072$   
 Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 18.00$   
 Mean strength value of all re-bars:  $f_y = 444.44$   
 $fc' = 20.00$ , but  $fc'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.61799$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$   
 where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = 150.00$   
 $n = 16.00$

-----  
 -----  
 - Calculation of  $p$  -  
 -----

From table 10-8:  $p = 0.00$   
 with:  
 - Columns not controlled by inadequate development or splicing along the clear height because  $l_b/d \geq 1$   
 shear control ratio  $V_y E / V_{CoIOE} = 0.62612363$   
 $d = 557.00$   
 $s = 0.00$   
 $t = Av / (bw \cdot s) + 2 \cdot tf / bw \cdot (ffe / fs) = Av \cdot L_{\text{stir}} / (Ag \cdot s) + 2 \cdot tf / bw \cdot (ffe / fs) = 0.00$   
 $Av = 78.53982$ , is the area of every stirrup  
 $L_{\text{stir}} = 1460.00$ , is the total Length of all stirrups parallel to loading (shear) direction

The term  $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$  is implemented to account for FRP contribution where  $f = 2 \cdot t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength. All these variables have already been given in Shear control ratio calculation.

$$NUD = 9662.362$$

$$A_g = 237500.00$$

$$f_{cE} = 20.00$$

$$f_{tE} = f_{yE} = 0.00$$

$$p_l = \text{Area\_Tot\_Long\_Rein} / (b \cdot d) = 0.02959978$$

$$b = 250.00$$

$$d = 557.00$$

$$f_{cE} = 20.00$$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

### Calculation No. 3

column C1, Floor 1

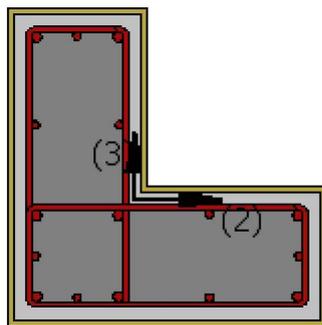
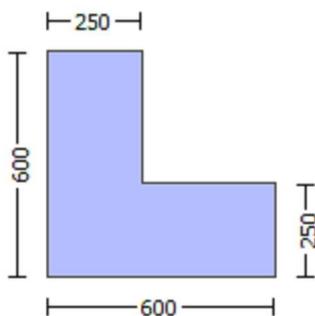
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

```

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Secondary Member: Concrete Strength, fc = fc_lower_bound = 16.00
Existing material of Secondary Member: Steel Strength, fs = fs_lower_bound = 400.00
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE41-17).
Existing material: Concrete Strength, fc = fcm = 20.00
Existing material: Steel Strength, fs = fsm = 444.44
#####
Max Height, Hmax = 600.00
Min Height, Hmin = 250.00
Max Width, Wmax = 600.00
Min Width, Wmin = 250.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length lo = lb = 300.00
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, ffu = 1055.00
Tensile Modulus, Ef = 64828.00
Elongation, efu = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

Stepwise Properties
-----
EDGE -A-
Bending Moment, Ma = -320830.403
Shear Force, Va = 148.2786
EDGE -B-
Bending Moment, Mb = -122390.945
Shear Force, Vb = -148.2786
BOTH EDGES
Axial Force, F = -9662.362
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Asc = 4121.77
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1746.726
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 1545.664
Mean Diameter of Tension Reinforcement, DbL,ten = 17.71429
-----
-----

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity VR =  $\phi V_n$  = 292301.036
Vn ((10.3), ASCE 41-17) = knl*VColo = 379611.735
VCol = 379611.735
knl = 1.00
displacement_ductility_demand = 0.00940177
-----

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+  $\phi V_f$ '

```

where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 16.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 320830.403$

$V_u = 148.2786$

$d = 0.8 \cdot h = 480.00$

$N_u = 9662.362$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 284837.734$

where:

$V_{s1} = 201061.93$  is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.3125$

$V_{s2} = 83775.804$  is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.75$

$V_f$  ((11-3)-(11.4), ACI 440) = 293495.545

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

orientation 1:  $\alpha_1 = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 557.00

$f_{fe}$  ((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:  $V_s + V_f \leq 318865.838$

$b_w = 250.00$

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  $\theta = 4.7459577E-005$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00504794$  ((4.29), Biskinis Phd)

$M_y = 2.9341E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 2163.70

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9662.362$

$E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment  $M_y$

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

```

y = Min( y_ten, y_com)
y_ten = 4.0518245E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^ 2/3) = 277.9106
d = 557.00
y = 0.3842998
A = 0.02984946
B = 0.0192317
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9662.362
b = 250.00
" = 0.07719928
y_comp = 8.1947240E-006
with fc* (12.3, (ACI 440)) = 20.42407
fc = 20.00
fl = 0.62098351
b = bmax = 600.00
h = hmax = 600.00
Ag = 237500.00
g = pt + pc + pv = 0.02959978
rc = 40.00
Ae/Ac = 0.21783041
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 = 21019.039
y = 0.38318842
A = 0.02940142
B = 0.01898202
with Es = 200000.00

```

Calculation of ratio lb/d

Lap Length:  $l_d/l_{d,min} = 0.3538123$

lb = 300.00

ld = 847.9072

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

= 1

db = 18.00

Mean strength value of all re-bars:  $f_y = 444.44$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.61799

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

s = 150.00

n = 16.00

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 4

column C1, Floor 1

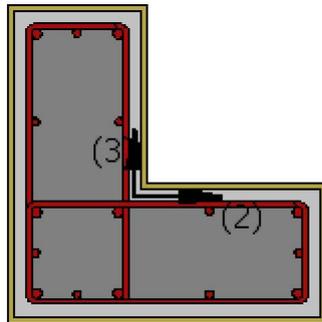
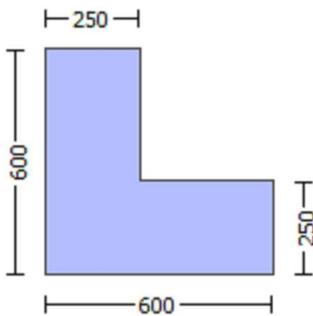
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$

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

Consequently:

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 0.00016213$

EDGE -B-

Shear Force,  $V_b = -0.00016213$

BOTH EDGES

Axial Force,  $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression:  $A_{sl,c} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1746.726$

-Compression:  $A_{sl,com} = 829.3805$

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

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.62612363$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.9843E+008$

$M_{u1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.9843E+008$

$M_{u2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $M_{u1+}$

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

$\phi_u = 1.1848408E-005$

$M_u = 3.9843E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.0144353$

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

From (5.4b), TBDY:  $c_u = 0.0144353$

$w_e$  ((5.4c), TBDY) =  $a_{se} \cdot s_{h,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

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)

$f_x = 0.06888919$

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

$a_f = 0.24098246$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

$f_y = 0.06888919$

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

$a_f = 0.24098246$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) \cdot (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$  ((5.4d), TBDY) =  $L_{stir} \cdot A_{stir}/(A_{sec} \cdot s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$p_{sh,y}$  ((5.4d), TBDY) =  $L_{stir} \cdot A_{stir}/(A_{sec} \cdot s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.00298102$

$c$  = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

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

Shear\_factor = 1.00

lo/lou,min = lb/d = 0.28304984

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

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

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

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

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

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

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

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

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

lo/lou,min = lb/d = 0.28304984

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

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

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.18776209

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.08915322

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.16614919

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.26111925

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.12398468

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.23106236

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) = 0.32281672

Mu = MRc (4.15) = 3.9843E+008

u = su (4.1) = 1.1848408E-005

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars:  $f_y = 555.55$

$f_c' = 20.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 150.00$

$n = 16.00$

Calculation of  $\mu_1$ -

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

$\mu = 9.6917274E-006$

$\mu = 2.1970E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$f_c = 20.00$

$\alpha_1 = 0.85$  (5A.5, TBDY) = 0.002

Final value of  $\mu$ :  $\mu = \text{shear\_factor} * \text{Max}(\mu_c, \mu_s) = 0.0144353$

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

From (5.4b), TBDY:  $\mu_c = 0.0144353$

where  $\mu_s = \alpha_1 * \text{Min}(f_{yk}/f_{ck}, f_{yk}/f_{yk}) = 0.07473805$

where  $f = \alpha_1 * \text{Min}(f_{yk}/f_{ck}, f_{yk}/f_{yk})$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06888919$

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

$\alpha_1 = 0.24098246$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $\alpha_1 = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{fe} = 703.4155$

$f_y = 0.06888919$

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

$\alpha_1 = 0.24098246$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $\alpha_1 = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{fe} = 703.4155$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00321875$$

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

$$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$$fy_1 = 299.3701$$

$$su_1 = 0.00446911$$

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

$$l_o/l_{o,min} = l_b/l_d = 0.28304984$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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

For calculation of  $esu_{1,nominal}$  and  $y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 299.3701$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00124738$$

$$sh_2 = 0.00431097$$

$$ft_2 = 359.2441$$

$$fy_2 = 299.3701$$

$$su_2 = 0.00446911$$

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

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 299.3701$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00124738$$

$$sh_v = 0.00431097$$

$$f_{tv} = 359.2441$$

$$f_{yv} = 299.3701$$

$$s_{uv} = 0.00446911$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.28304984$$

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

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

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

For calculation of  $e_{suv,nominal}$  and  $\gamma_v$ ,  $sh_v, f_{tv}, f_{yv}$ , it is considered  
characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$\gamma_1$ ,  $sh_1, f_{t1}, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 299.3701$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03714718$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.0782342$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.06922883$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 21.96205$$

$$c_c (5A.5, TBDY) = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04362424$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09187529$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08129972$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.17212448$$

$$M_u = M_{Rc} (4.14) = 2.1970E+008$$

$$u = s_u (4.1) = 9.6917274E-006$$

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

-----  
Lap Length:  $l_b/l_d = 0.28304984$

$$l_b = 300.00$$

$$l_d = 1059.884$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

-----  
Calculation of  $M_u2+$

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

$$u = 1.1848408E-005$$

$$M_u = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear\_factor} * \text{Max}(\alpha, \alpha_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } \alpha = 0.0144353$$

$$\alpha_w \text{ ((5.4c), TBDY) } = \alpha_s * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$f_y = 0.06888919$$

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

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_s = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $\rho_{sh,\min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\rho_{sh,x} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 1460.00$$

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

$$A_{\text{sec}} \text{ (section area) } = 237500.00$$

$$\rho_{sh,y} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 1460.00$$

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

$$A_{\text{sec}} \text{ (section area) } = 237500.00$$

$$s = 150.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

From ((5.A.5), TBDY), TBDY:  $cc = 0.00298102$

$$c = \text{confinement factor} = 1.0981$$

$$y1 = 0.00124738$$

$$sh1 = 0.00431097$$

$$ft1 = 359.2441$$

$$fy1 = 299.3701$$

$$su1 = 0.00446911$$

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

$$lo/lou,min = lb/ld = 0.28304984$$

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

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, ASCE41-17.

$$\text{with } fs1 = fs = 299.3701$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00124738$$

$$sh2 = 0.00431097$$

$$ft2 = 359.2441$$

$$fy2 = 299.3701$$

$$su2 = 0.00446911$$

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

$$lo/lou,min = lb/lb,min = 0.28304984$$

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

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, ASCE41-17.

$$\text{with } fs2 = fs = 299.3701$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00124738$$

$$shv = 0.00431097$$

$$ftv = 359.2441$$

$$fyv = 299.3701$$

$$suv = 0.00446911$$

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

$$lo/lou,min = lb/ld = 0.28304984$$

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

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

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 299.3701$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 21.96205$$

$$cc (5A.5, TBDY) = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236$$

Case/Assumption: Unconfinedsd 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

---->

$\mu$  (4.8) = 0.32281672

$\mu = M_{Rc}$  (4.15) = 3.9843E+008

$u = \mu$  (4.1) = 1.1848408E-005

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

Lap Length:  $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

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

= 1

$d_b = 18.00$

Mean strength value of all re-bars:  $f_y = 555.55$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 150.00$

$n = 16.00$

-----  
Calculation of  $\mu_2$

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

$u = 9.6917274E-006$

$\mu = 2.1970E+008$

-----  
with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$f_c = 20.00$

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

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu, \alpha) = 0.0144353$

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

From (5.4b), TBDY:  $\mu = 0.0144353$

where  $\mu = \alpha * \text{sh}_{\min} * f_y w_e / f_c e + \text{Min}(f_x, f_y) = 0.07473805$

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

$f_x = 0.06888919$

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

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{fe} = 703.4155$

$f_y = 0.06888919$

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

af = 0.24098246  
with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$   
bmax = 600.00  
hmax = 600.00  
From EC8 A.4.4.3(6), pf =  $2t_f/b_w = 0.008128$   
bw = 250.00  
effective stress from (A.35), ff,e = 703.4155

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 =  $Max(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.21805635$   
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,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 105733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min =  $Min(psh,x, psh,y) = 0.00321875$

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

psh,x ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$   
Lstir (Length of stirrups along Y) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$   
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00  
fywe = 555.55  
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102  
c = confinement factor = 1.0981

y1 = 0.00124738  
sh1 = 0.00431097

ft1 = 359.2441  
fy1 = 299.3701

su1 = 0.00446911

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

lo/lou,min =  $l_b/l_d = 0.28304984$

su1 =  $0.4*es_{u1\_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: es<sub>u1\_nominal</sub> = 0.08,

For calculation of es<sub>u1\_nominal</sub> and y1, sh1, ft1, fy1, it is considered characteristic value fs<sub>y1</sub> = fs<sub>1/1.2</sub>, 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, ASCE41-17.

with fs<sub>1</sub> = fs = 299.3701

with Es<sub>1</sub> = Es = 200000.00

y2 = 0.00124738  
sh2 = 0.00431097

ft2 = 359.2441  
fy2 = 299.3701

su2 = 0.00446911

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

Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

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, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

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

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

Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.28304984

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

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

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.03714718

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0782342

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06922883

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04362424

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09187529

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.08129972

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.17212448

Mu = MRc (4.14) = 2.1970E+008

u = su (4.1) = 9.6917274E-006

-----  
Calculation of ratio lb/ld

-----  
Lap Length: lb/ld = 0.28304984

lb = 300.00

ld = 1059.884

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

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 20.00, but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.61799

Atr =  $\text{Min}(Atr_x, Atr_y)$  = 157.0796

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

s = 150.00

$$n = 16.00$$

$$\text{Calculation of Shear Strength } V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$$

$$\text{Calculation of Shear Strength at edge 1, } V_{r1} = 424229.688$$

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

$$V_{\text{ColO}} = 424229.688$$

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

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 47.24078$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 316483.206$$

where:

$V_{s1} = 223399.91$  is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$$s/d = 0.3125$$

$V_{s2} = 93083.296$  is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$$s/d = 0.75$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$$

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

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

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

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

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

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 557.00$$

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 356502.845$$

$$b_w = 250.00$$

$$\text{Calculation of Shear Strength at edge 2, } V_{r2} = 424229.688$$

$$V_{r2} = V_{\text{Col}} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{\text{ColO}}$$

$$V_{\text{ColO}} = 424229.688$$

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

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 47.24081$   
 $V_u = 0.00016213$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 8883.864$   
 $A_g = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$   
 where:  
 $V_{s1} = 223399.91$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 93083.296$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 293495.545  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = 45^\circ + 90^\circ = 135^\circ$   
 $V_f = \text{Min}(|V_f(45, a)|, |V_f(-45, a)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 557.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 356502.845$   
 $b_w = 250.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At local axis: 3

-----  
 Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rclcs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 0.77$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
 #####

Max Height, Hmax = 600.00  
Min Height, Hmin = 250.00  
Max Width, Wmax = 600.00  
Min Width, Wmin = 250.00  
Cover Thickness, c = 25.00  
Mean Confinement Factor overall section = 1.0981  
Element Length, L = 3000.00  
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length lo = 300.00  
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness, t = 1.016  
Tensile Strength, ffu = 1055.00  
Tensile Modulus, Ef = 64828.00  
Elongation, efu = 0.01  
Number of directions, NoDir = 1  
Fiber orientations, bi: 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

-----  
Stepwise Properties  
-----

At local axis: 2  
EDGE -A-  
Shear Force, Va = 0.00016213  
EDGE -B-  
Shear Force, Vb = -0.00016213  
BOTH EDGES  
Axial Force, F = -8883.864  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 4121.77  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 1746.726  
-Compression: Asl,com = 829.3805  
-Middle: Asl,mid = 1545.664  
-----  
-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.62612363$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$   
with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 3.9843E+008$

$\mu_{u1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 3.9843E+008$

$\mu_{u2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$\mu_{u2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

-----  
Calculation of  $\mu_{u1+}$   
-----  
-----

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

u = 1.1848408E-005  
Mu = 3.9843E+008

with full section properties:

b = 250.00  
d = 557.00  
d' = 43.00  
v = 0.0031899  
N = 8883.864  
fc = 20.00  
co (5A.5, TBDY) = 0.002

Final value of cu:  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.0144353$

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

From (5.4b), TBDY:  $cu = 0.0144353$

we ((5.4c), TBDY) =  $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07473805$

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

fx = 0.06888919

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

af = 0.24098246

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$

bmax = 600.00

hmax = 600.00

From EC8 A 4.4.3(6),  $pf = 2tf / bw = 0.008128$

bw = 250.00

effective stress from (A.35),  $ff_{e} = 703.4155$

fy = 0.06888919

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

af = 0.24098246

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

bmax = 600.00

hmax = 600.00

From EC8 A 4.4.3(6),  $pf = 2tf / bw = 0.008128$

bw = 250.00

effective stress from (A.35),  $ff_{e} = 703.4155$

R = 40.00

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

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase =  $\text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $bi^2/6$  as defined at (A.2).

$psh_{\min} = \text{Min}(psh_x, psh_y) = 0.00321875$

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

$psh_x$  ((5.4d), TBDY) =  $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$

$L_{\text{stir}}$  (Length of stirrups along Y) = 1460.00

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

$A_{\text{sec}}$  (section area) = 237500.00

$psh_y$  ((5.4d), TBDY) =  $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$

$L_{\text{stir}}$  (Length of stirrups along X) = 1460.00

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

$A_{\text{sec}}$  (section area) = 237500.00

$s = 150.00$   
 $fy_{we} = 555.55$   
 $f_{ce} = 20.00$   
 From ((5.A.5), TBDY), TBDY:  $cc = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $y_1 = 0.00124738$   
 $sh_1 = 0.00431097$   
 $ft_1 = 359.2441$   
 $fy_1 = 299.3701$   
 $su_1 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/d = 0.28304984$   
 $su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esu_1 \text{ nominal} = 0.08$ ,  
 For calculation of  $esu_1 \text{ nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_1 = fs = 299.3701$   
 with  $Es_1 = Es = 200000.00$   
 $y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $fy_2 = 299.3701$   
 $su_2 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/lb, \min = 0.28304984$   
 $su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esu_2 \text{ nominal} = 0.08$ ,  
 For calculation of  $esu_2 \text{ nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_2 = fs = 299.3701$   
 with  $Es_2 = Es = 200000.00$   
 $y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $fy_v = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou, \min = lb/d = 0.28304984$   
 $suv = 0.4 * esuv \text{ nominal ((5.5), TBDY)} = 0.032$   
 From table 5A.1, TBDY:  $esuv \text{ nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv \text{ nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_v = fs = 299.3701$   
 with  $Es_v = Es = 200000.00$   
 $1 = Asl, \text{ten}/(b * d) * (fs_1/fc) = 0.18776209$   
 $2 = Asl, \text{com}/(b * d) * (fs_2/fc) = 0.08915322$   
 $v = Asl, \text{mid}/(b * d) * (fs_v/fc) = 0.16614919$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} \text{ (5A.2, TBDY)} = 21.96205$   
 $cc \text{ (5A.5, TBDY)} = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = Asl, \text{ten}/(b * d) * (fs_1/fc) = 0.26111925$   
 $2 = Asl, \text{com}/(b * d) * (fs_2/fc) = 0.12398468$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.23106236$$

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

--->

$$s_u(4.8) = 0.32281672$$

$$M_u = M_{Rc}(4.15) = 3.9843E+008$$

$$u = s_u(4.1) = 1.1848408E-005$$

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

Lap Length:  $l_b/l_d = 0.28304984$

$$l_b = 300.00$$

$$l_d = 1059.884$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$f'_c = 20.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

-----  
Calculation of  $M_u1$ -

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

$$u = 9.6917274E-006$$

$$M_u = 2.1970E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} \cdot \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$w_e((5.4c), TBDY) = a_{se} \cdot s_{h, min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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)

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.008128$

$$b_w = 250.00$$

effective stress from (A.35),  $f_{f,e} = 703.4155$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$L_{\text{stir}}$  (Length of stirrups along Y) = 1460.00

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

$A_{\text{sec}}$  (section area) = 237500.00

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$L_{\text{stir}}$  (Length of stirrups along X) = 1460.00

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

$A_{\text{sec}}$  (section area) = 237500.00

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

From ((5.A5), TBDY), TBDY:  $c_c = 0.00298102$

$c$  = confinement factor = 1.0981

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$$fy_1 = 299.3701$$

$$su_1 = 0.00446911$$

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

$$l_o/l_{o,min} = l_b/l_d = 0.28304984$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$$y_2 = 0.00124738$$

$$sh_2 = 0.00431097$$

$$ft_2 = 359.2441$$

$$fy_2 = 299.3701$$

$$su_2 = 0.00446911$$

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

lo/lou,min = lb/lb,min = 0.28304984

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, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

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

lo/lou,min = lb/ld = 0.28304984

su = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

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

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.03714718

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0782342

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06922883

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04362424

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09187529

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.08129972

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.17212448

Mu = MRc (4.14) = 2.1970E+008

u = su (4.1) = 9.6917274E-006

-----  
Calculation of ratio lb/ld

-----  
Lap Length: lb/ld = 0.28304984

lb = 300.00

ld = 1059.884

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

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 20.00, but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.61799

Atr =  $\text{Min}(Atr_x, Atr_y)$  = 157.0796

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

$$s = 150.00$$

$$n = 16.00$$

-----  
-----  
-----  
Calculation of  $\mu_{2+}$   
-----

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

$$\mu = 1.1848408E-005$$

$$\mu_{2+} = 3.9843E+008$$

-----  
with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,\min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without

earthquake detailing (90° closed stirrups)

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00321875$$

$$Lstir (\text{Length of stirrups along } Y) = 1460.00$$

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

$$Asec (\text{section area}) = 237500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00321875$$

$$Lstir (\text{Length of stirrups along } X) = 1460.00$$

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

$$Asec (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y1 = 0.00124738$$

$$sh1 = 0.00431097$$

$$ft1 = 359.2441$$

$$fy1 = 299.3701$$

$$su1 = 0.00446911$$

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

$$lo/lou,min = lb/ld = 0.28304984$$

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

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, ASCE41-17.

$$\text{with } fs1 = fs = 299.3701$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00124738$$

$$sh2 = 0.00431097$$

$$ft2 = 359.2441$$

$$fy2 = 299.3701$$

$$su2 = 0.00446911$$

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

$$lo/lou,min = lb/lb,min = 0.28304984$$

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

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, ASCE41-17.

$$\text{with } fs2 = fs = 299.3701$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00124738$$

$$shv = 0.00431097$$

$$ftv = 359.2441$$

$$fyv = 299.3701$$

$$suv = 0.00446911$$

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

$$lo/lou,min = lb/ld = 0.28304984$$

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

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

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 299.3701$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.18776209$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08915322$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.16614919$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 21.96205$$

$$c_c (5A.5, TBDY) = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$$

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

--->

$$s_u (4.8) = 0.32281672$$

$$M_u = M_{Rc} (4.15) = 3.9843E+008$$

$$u = s_u (4.1) = 1.1848408E-005$$

-----  
Calculation of ratio  $l_b/d$

-----  
Lap Length:  $l_b/d = 0.28304984$

$$l_b = 300.00$$

$$l_d = 1059.884$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$$f'_c = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

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

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

$$u = 9.6917274E-006$$

$$M_u = 2.1970E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$\text{where ((5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.008128$

$$b_w = 250.00$$

effective stress from (A.35),  $f_{f,e} = 703.4155$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.008128$

$$b_w = 250.00$$

effective stress from (A.35),  $f_{f,e} = 703.4155$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$$

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)

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$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

From ((5.A5), TBDY), TBDY:  $c_c = 0.00298102$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$$fy_1 = 299.3701$$

$$su_1 = 0.00446911$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.28304984$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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  $Min(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs1 = fs = 299.3701$

with  $Es1 = Es = 200000.00$

$y2 = 0.00124738$

$sh2 = 0.00431097$

$ft2 = 359.2441$

$fy2 = 299.3701$

$su2 = 0.00446911$

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

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

$Shear\_factor = 1.00$

$lo/lou, min = lb/lb, min = 0.28304984$

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

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, ASCE41-17.

with  $fs2 = fs = 299.3701$

with  $Es2 = Es = 200000.00$

$yv = 0.00124738$

$shv = 0.00431097$

$ftv = 359.2441$

$fyv = 299.3701$

$suv = 0.00446911$

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

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

$Shear\_factor = 1.00$

$lo/lou, min = lb/ld = 0.28304984$

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

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, ASCE41-17.

with  $fsv = fs = 299.3701$

with  $Esv = Es = 200000.00$

$1 = Asl, ten / (b * d) * (fs1 / fc) = 0.03714718$

$2 = Asl, com / (b * d) * (fs2 / fc) = 0.0782342$

$v = Asl, mid / (b * d) * (fsv / fc) = 0.06922883$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 21.96205$

$cc (5A.5, TBDY) = 0.00298102$

$c =$  confinement factor  $= 1.0981$

$1 = Asl, ten / (b * d) * (fs1 / fc) = 0.04362424$

$2 = Asl, com / (b * d) * (fs2 / fc) = 0.09187529$

$v = Asl, mid / (b * d) * (fsv / fc) = 0.08129972$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

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

---

$su (4.9) = 0.17212448$

$Mu = MRc (4.14) = 2.1970E+008$

$u = su (4.1) = 9.6917274E-006$

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

Lap Length:  $lb/ld = 0.28304984$

$lb = 300.00$

$ld = 1059.884$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$$f'_c = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1,  $V_{r1} = 424229.688$

$$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$$

$$V_{Col0} = 424229.688$$

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

NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_{s+ f*V_f}$ '

where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f'_c = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$\mu_u = 47.23669$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 316483.206$$

where:

$V_{s1} = 93083.296$  is calculated for section web, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$$s/d = 0.75$$

$V_{s2} = 223399.91$  is calculated for section flange, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$$s/d = 0.3125$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$$

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

$w_f/s_f = 1$  (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  $\alpha$  is the angle of the crack direction (see KANEPE).

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

$$\text{orientation 1: } \alpha = b_1 + 90^\circ = 90.00$$

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 557.00$$

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

$$E_f = 64828.00$$

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

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

From (11-11), ACI 440:  $V_s + V_f \leq 356502.845$   
 $bw = 250.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 424229.688$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 424229.688$   
 $knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf'  
where Vf is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)  
 $f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $M_u = 47.23667$   
 $V_u = 0.00016213$   
 $d = 0.8 * h = 480.00$   
 $N_u = 8883.864$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 93083.296$  is calculated for section web, with:

$d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.75$

$V_{s2} = 223399.91$  is calculated for section flange, with:

$d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.3125$

$V_f ((11-3)-(11.4), ACI 440) = 293495.545$

$f = 0.95$ , 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,  $tf_1 = NL * t / NoDir = 1.016$

$dfv = d$  (figure 11.2, ACI 440) = 557.00

$ffe ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 356502.845$

$bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1  
At local axis: 3  
Integration Section: (a)  
Section Type: rdc

Constant Properties

-----

Knowledge Factor,  $\phi = 0.77$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

-----

#### Stepwise Properties

-----

Bending Moment,  $M = -1.2946E+007$

Shear Force,  $V_2 = -4259.045$

Shear Force,  $V_3 = 148.2786$

Axial Force,  $F = -9662.362$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{st,ten} = 1746.726$

-Compression:  $A_{sc,com} = 829.3805$

-Middle:  $A_{s,mid} = 1545.664$

Mean Diameter of Tension Reinforcement,  $D_{bL} = 17.71429$

-----

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = \phi \cdot u = 0.0054603$

$u = y + p = 0.0070913$

-----

- Calculation of  $y$  -

-----

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.0070913$  ((4.29), Biskinis Phd))

$M_y = 2.9341E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3039.546

From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9662.362$

$E_c \cdot I_g = 1.3974E+014$

-----  
-----  
Calculation of Yielding Moment  $M_y$

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

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

$$y_{\text{ten}} = 4.0518245\text{E-}006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 277.9106$$

$$d = 557.00$$

$$y = 0.3842998$$

$$A = 0.02984946$$

$$B = 0.0192317$$

$$\text{with } p_t = 0.01254381$$

$$p_c = 0.00595605$$

$$p_v = 0.01109992$$

$$N = 9662.362$$

$$b = 250.00$$

$$" = 0.07719928$$

$$y_{\text{comp}} = 8.1947240\text{E-}006$$

$$\text{with } f_c^* (12.3, (\text{ACI 440})) = 20.42407$$

$$f_c = 20.00$$

$$f_l = 0.62098351$$

$$b = b_{\text{max}} = 600.00$$

$$h = h_{\text{max}} = 600.00$$

$$A_g = 237500.00$$

$$g = p_t + p_c + p_v = 0.02959978$$

$$r_c = 40.00$$

$$A_e/A_c = 0.21783041$$

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

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.38318842$$

$$A = 0.02940142$$

$$B = 0.01898202$$

$$\text{with } E_s = 200000.00$$

-----  
-----  
Calculation of ratio  $l_b/d$

$$\text{Lap Length: } l_d/l_d, \text{min} = 0.3538123$$

$$l_b = 300.00$$

$$l_d = 847.9072$$

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

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 444.44$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

-----  
-----  
- Calculation of  $\rho_p$  -

From table 10-8:  $\rho_p = 0.00$

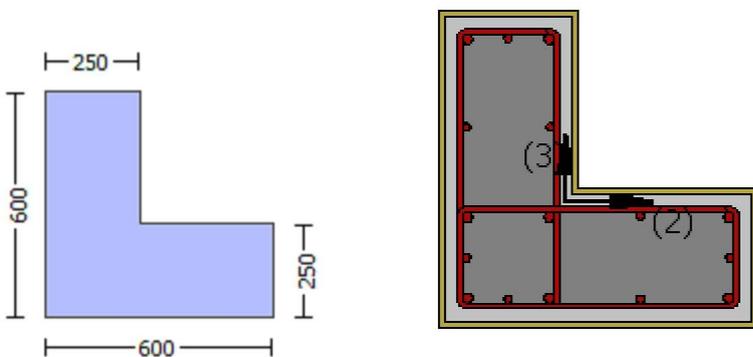
with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/l_d \geq 1$   
 shear control ratio  $V_{yE}/V_{CoIE} = 0.62612363$   
 $d = 557.00$   
 $s = 0.00$   
 $t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$   
 $A_v = 78.53982$ , is the area of every stirrup  
 $L_{stir} = 1460.00$ , is the total Length of all stirrups parallel to loading (shear) direction  
 The term  $2*t_f/b_w*(f_{fe}/f_s)$  is implemented to account for FRP contribution  
 where  $f = 2*t_f/b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe}/f_s$  normalises  $f$  to steel strength  
 All these variables have already been given in Shear control ratio calculation.  
 $NUD = 9662.362$   
 $A_g = 237500.00$   
 $f_{cE} = 20.00$   
 $f_{ytE} = f_{ylE} = 0.00$   
 $\rho_l = Area_{Tot\_Long\_Rein}/(b*d) = 0.02959978$   
 $b = 250.00$   
 $d = 557.00$   
 $f_{cE} = 20.00$

-----  
 End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1  
 At local axis: 3  
 Integration Section: (a)

## Calculation No. 5

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



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1  
 At local axis: 2

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

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

Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -1.2946E+007$

Shear Force,  $V_a = -4259.045$

EDGE -B-

Bending Moment,  $M_b = 164093.879$

Shear Force,  $V_b = 4259.045$

BOTH EDGES

Axial Force,  $F = -9662.362$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1746.726$

-Compression:  $As_{l,com} = 829.3805$

-Middle:  $As_{l,mid} = 1545.664$

Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 339075.376$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoIO} = 440357.631$   
 $V_{CoI} = 440357.631$   
 $k_n = 1.00$   
displacement\_ductility\_demand = 0.06818797

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs +  $\phi V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)  
 $f_c' = 16.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 164093.879$   
 $V_u = 4259.045$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 9662.362$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 284837.734$

where:

$V_{s1} = 83775.804$  is calculated for section web, with:

$d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 150.00$

$V_{s1}$  is multiplied by  $Co1 = 1.00$

$s/d = 0.75$

$V_{s2} = 201061.93$  is calculated for section flange, with:

$d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 150.00$

$V_{s2}$  is multiplied by  $Co2 = 1.00$

$s/d = 0.3125$

$V_f$  ((11-3)-(11.4), ACI 440) = 293495.545

$\phi = 0.95$ , for fully-wrapped sections

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

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

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

orientation 1:  $\theta = 45^\circ + 90^\circ = 135^\circ$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 557.00

$f_{fe}$  ((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:  $V_s + V_f \leq 318865.838$

$b_w = 250.00$

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  $\theta = 4.7725017E-005$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.0006999$  ((4.29), Biskinis Phd)

$M_y = 2.9341E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 300.00

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9662.362$

$$E_c \cdot I_g = 1.3974E+014$$

Calculation of Yielding Moment  $M_y$

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

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

$$y_{\text{ten}} = 4.0518245E-006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) \quad f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 277.9106$$

$$d = 557.00$$

$$y = 0.3842998$$

$$A = 0.02984946$$

$$B = 0.0192317$$

$$\text{with } p_t = 0.01254381$$

$$p_c = 0.00595605$$

$$p_v = 0.01109992$$

$$N = 9662.362$$

$$b = 250.00$$

$$\lambda = 0.07719928$$

$$y_{\text{comp}} = 8.1947240E-006$$

$$\text{with } f_c^* (12.3, \text{ACI 440}) = 20.42407$$

$$f_c = 20.00$$

$$f_l = 0.62098351$$

$$b = b_{\text{max}} = 600.00$$

$$h = h_{\text{max}} = 600.00$$

$$A_g = 237500.00$$

$$g = p_t + p_c + p_v = 0.02959978$$

$$r_c = 40.00$$

$$A_e/A_c = 0.21783041$$

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

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.38318842$$

$$A = 0.02940142$$

$$B = 0.01898202$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio  $l_b/d$

$$\text{Lap Length: } l_d/d, \text{min} = 0.3538123$$

$$l_b = 300.00$$

$$l_d = 847.9072$$

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

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 444.44$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 6

column C1, Floor 1

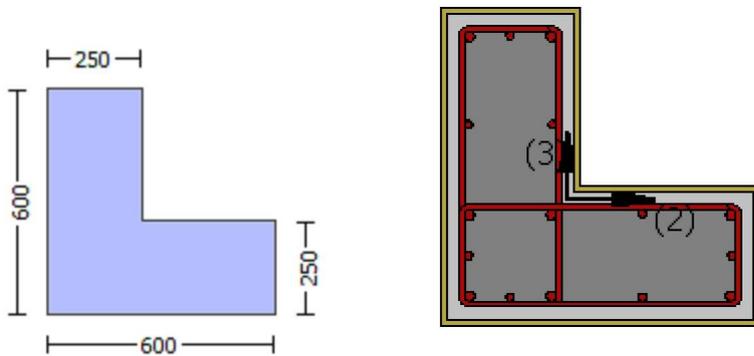
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdc

Constant Properties

Knowledge Factor,  $\phi = 0.77$

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

Consequently:

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
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,  $V_a = 0.00016213$   
EDGE -B-  
Shear Force,  $V_b = -0.00016213$   
BOTH EDGES  
Axial Force,  $F = -8883.864$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 4121.77$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 1746.726$   
-Compression:  $As_{l,com} = 829.3805$   
-Middle:  $As_{l,mid} = 1545.664$

-----  
-----  
Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.62612363$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$   
with  
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 3.9843E+008$   
 $Mu_{1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
which is defined for the static loading combination  
 $Mu_{1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 3.9843E+008$   
 $Mu_{2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
which is defined for the the static loading combination  
 $Mu_{2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment  
direction which is defined for the the static loading combination

-----  
Calculation of  $Mu_{1+}$   
-----

-----  
Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
 $\phi_u = 1.1848408E-005$   
 $M_u = 3.9843E+008$

-----  
with full section properties:

$b = 250.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.0031899$   
 $N = 8883.864$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$\text{we ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$f_{y1} = 299.3701$   
 $s_{u1} = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.28304984$   
 $s_{u1} = 0.4 * e_{s1\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{s1\_nominal} = 0.08$ ,  
 For calculation of  $e_{s1\_nominal}$  and  $y_1, sh_1, ft_1, f_{y1}$ , it is considered  
 characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{s1} = f_s = 299.3701$   
 with  $E_{s1} = E_s = 200000.00$   
 $y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $f_{y2} = 299.3701$   
 $s_{u2} = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$   
 $s_{u2} = 0.4 * e_{s2\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{s2\_nominal} = 0.08$ ,  
 For calculation of  $e_{s2\_nominal}$  and  $y_2, sh_2, ft_2, f_{y2}$ , it is considered  
 characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.  
 $y_2, sh_2, ft_2, f_{y2}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{s2} = f_s = 299.3701$   
 with  $E_{s2} = E_s = 200000.00$   
 $y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $f_{yv} = 299.3701$   
 $s_{uv} = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.28304984$   
 $s_{uv} = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{suv\_nominal} = 0.08$ ,  
 considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $e_{suv\_nominal}$  and  $y_v, sh_v, ft_v, f_{yv}$ , it is considered  
 characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{sv} = f_s = 299.3701$   
 with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.18776209$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08915322$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.16614919$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$   
 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  
 --->  
 $su (4.8) = 0.32281672$

$$\begin{aligned} \mu_u &= M/R_c (4.15) = 3.9843E+008 \\ u &= s_u (4.1) = 1.1848408E-005 \end{aligned}$$

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

Lap Length:  $l_b/l_d = 0.28304984$

$$l_b = 300.00$$

$$l_d = 1059.884$$

Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

$$d_b = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

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

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

$$u = 9.6917274E-006$$

$$\mu_u = 2.1970E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$\text{we ((5.4c), TBDY) } = a_s e^* \text{ sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$  ((5.4d), TBDY) =  $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$p_{sh,y}$  ((5.4d), TBDY) =  $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c$  = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

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

$l_o/l_{o,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 \cdot esu_{1,nominal}$  ((5.5), TBDY) = 0.032

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

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$

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

From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,

For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{s2} = f_s = 299.3701$   
 with  $E_{s2} = E_s = 200000.00$   
 $y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $fy_v = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.28304984$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{sv} = f_s = 299.3701$   
 with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.03714718$   
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.0782342$   
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.06922883$

and confined core properties:

$b = 540.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.04362424$   
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09187529$   
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.08129972$

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

---

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

---

$su (4.9) = 0.17212448$   
 $Mu = MRc (4.14) = 2.1970E+008$   
 $u = su (4.1) = 9.6917274E-006$

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

Lap Length:  $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

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

= 1

$db = 18.00$

Mean strength value of all re-bars:  $f_y = 555.55$

$f'_c = 20.00$ , but  $f'_c^{0.5} < 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 150.00$

$n = 16.00$   
 -----  
 -----  
 -----

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

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

$$u = 1.1848408E-005$$

$$Mu = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00318999$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_{cu}: \phi_{cu}^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.0144353$$

$$\phi_{we} (5.4c, TBDY) = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07473805$$

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

$$\phi_{fx} = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$\phi_{fy} = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$\phi_{psh, \min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.00321875$$

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

$$\phi_{psh,x} (5.4d, TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} (\text{Length of stirrups along } Y) = 1460.00$$

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

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$\phi_{psh,y} (5.4d, TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} (\text{Length of stirrups along } X) = 1460.00$$

Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00

fywe = 555.55

fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.00124738

sh1 = 0.00431097

ft1 = 359.2441

fy1 = 299.3701

su1 = 0.00446911

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

lo/lou,min = lb/lb = 0.28304984

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, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

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

lo/lou,min = lb/lb,min = 0.28304984

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, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

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

lo/lou,min = lb/lb = 0.28304984

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, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.18776209

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.08915322

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.16614919

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$$

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) = 0.32281672  
 $M_u = M_{Rc}$  (4.15) = 3.9843E+008  
 $u = \mu_u$  (4.1) = 1.1848408E-005

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.28304984$

$$l_b = 300.00$$

$$l_d = 1059.884$$

Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

$$d_b = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$f'_c = 20.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

Calculation of  $\mu_u$

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

$$u = 9.6917274E-006$$

$$M_u = 2.1970E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.0144353$$

$$\text{we ((5.4c), TBDY) } = a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A 4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

effective stress from (A.35),  $f_{f,e} = 703.4155$

$f_y = 0.06888919$

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

$a_f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$

$L_{\text{stir}}$  (Length of stirrups along Y) = 1460.00

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

$A_{\text{sec}}$  (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$

$L_{\text{stir}}$  (Length of stirrups along X) = 1460.00

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

$A_{\text{sec}}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c$  = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

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

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

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

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fs_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$$f_y2 = 299.3701$$

$$s_u2 = 0.00446911$$

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

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$$

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{su2,nominal} = 0.08$ ,

For calculation of  $e_{su2,nominal}$  and  $y_2$ ,  $sh_2, ft_2, f_y2$ , 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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 299.3701$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00124738$$

$$sh_v = 0.00431097$$

$$f_{tv} = 359.2441$$

$$f_{yv} = 299.3701$$

$$s_{uv} = 0.00446911$$

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

$$l_o/l_{o,min} = l_b/l_d = 0.28304984$$

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

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

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

For calculation of  $e_{suv,nominal}$  and  $y_v$ ,  $sh_v, f_{tv}, f_{yv}$ , it is considered  
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1, ft_1, f_y1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 299.3701$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.03714718$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.0782342$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.06922883$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 21.96205$$

$$cc (5A.5, TBDY) = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.04362424$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09187529$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.08129972$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

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

---

$$s_u (4.9) = 0.17212448$$

$$\mu_u = M_{Rc} (4.14) = 2.1970E+008$$

$$u = s_u (4.1) = 9.6917274E-006$$

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

Lap Length:  $l_b/l_d = 0.28304984$

$$l_b = 300.00$$

$$l_d = 1059.884$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

$$\text{Calculation of Shear Strength } V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$$

$$\text{Calculation of Shear Strength at edge 1, } V_{r1} = 424229.688$$

$$V_{r1} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{CoI0}$$

$$V_{CoI0} = 424229.688$$

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

NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_s + f * V_f$ '

where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 47.24078$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 316483.206$$

where:

$V_{s1} = 223399.91$  is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$$s/d = 0.3125$$

$V_{s2} = 93083.296$  is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$$s/d = 0.75$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$$

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

$w_f/s_f = 1$  (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  $\alpha$  is the angle of the crack direction (see KANEPE).

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

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

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 557.00$$

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 356502.845$$

$$b_w = 250.00$$

$$\text{Calculation of Shear Strength at edge 2, } V_{r2} = 424229.688$$

$$V_{r2} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{CoI0}$$

$$V_{CoI0} = 424229.688$$

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

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf'  
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

fc' = 20.00, but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 47.24081

Vu = 0.00016213

d = 0.8\*h = 480.00

Nu = 8883.864

Ag = 150000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 316483.206

where:

Vs1 = 223399.91 is calculated for section web, with:

d = 480.00

Av = 157079.633

fy = 444.44

s = 150.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.3125

Vs2 = 93083.296 is calculated for section flange, with:

d = 200.00

Av = 157079.633

fy = 444.44

s = 150.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.75

Vf ((11-3)-(11.4), ACI 440) = 293495.545

f = 0.95, for fully-wrapped sections

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

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

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

This later relation, considered as a function Vf(  $\alpha$  ), is implemented for every different fiber orientation ai,

as well as for 2 crack directions,  $\alpha = 45^\circ$  and  $\alpha = -45^\circ$  to take into consideration the cyclic seismic loading.

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

Vf = Min(|Vf(45, 1)|, |Vf(-45, a1)|), with:

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

dfv = d (figure 11.2, ACI 440) = 557.00

ffe ((11-5), ACI 440) = 259.312

Ef = 64828.00

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

with fu = 0.01

From (11-11), ACI 440: Vs + Vf <= 356502.845

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\phi = 0.77$

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

Consequently:

Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00

Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity, Ec = 21019.039

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

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

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties

-----  
At local axis: 2

EDGE -A-

Shear Force,  $V_a = 0.00016213$

EDGE -B-

Shear Force,  $V_b = -0.00016213$

BOTH EDGES

Axial Force,  $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression:  $A_{sl,c} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1746.726$

-Compression:  $A_{sl,com} = 829.3805$

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

-----  
-----  
Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.62612363$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.9843E+008$

$\mu_{1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.9843E+008$

$\mu_{2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$\mu_{2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

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

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

$$\mu = 1.1848408E-005$$

$$\mu_u = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.0144353$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = \alpha s_e * \text{sh}_{,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$\alpha f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

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

$$\alpha f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,\min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00321875$$

$$Lstir \text{ (Length of stirrups along X)} = 1460.00$$

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

$$Asec \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y1 = 0.00124738$$

$$sh1 = 0.00431097$$

$$ft1 = 359.2441$$

$$fy1 = 299.3701$$

$$su1 = 0.00446911$$

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

$$lo/lou,min = lb/d = 0.28304984$$

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

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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 299.3701$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00124738$$

$$sh2 = 0.00431097$$

$$ft2 = 359.2441$$

$$fy2 = 299.3701$$

$$su2 = 0.00446911$$

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

$$lo/lou,min = lb/lb,min = 0.28304984$$

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

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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 299.3701$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00124738$$

$$shv = 0.00431097$$

$$ftv = 359.2441$$

$$fyv = 299.3701$$

$$suv = 0.00446911$$

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

$$lo/lou,min = lb/d = 0.28304984$$

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

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  $\text{Min}(1, 1.25 * (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 299.3701$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.18776209$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.08915322$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.16614919$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc \text{ (5A.2, TBDY)} = 21.96205$$

$$cc \text{ (5A.5, TBDY)} = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = \text{Asl,ten}/(b*d)*(fs1/fc) = 0.26111925$$

$$2 = \text{Asl,com}/(b*d)*(fs2/fc) = 0.12398468$$

$$v = \text{Asl,mid}/(b*d)*(fsv/fc) = 0.23106236$$

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

---->  
 $su \text{ (4.8)} = 0.32281672$

$$\text{Mu} = \text{MRc} \text{ (4.15)} = 3.9843\text{E}+008$$

$$u = su \text{ (4.1)} = 1.1848408\text{E}-005$$

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

-----  
Lap Length:  $l_b/l_d = 0.28304984$

$$l_b = 300.00$$

$$l_d = 1059.884$$

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

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 555.55$$

$$f_c' = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

-----  
Calculation of  $\text{Mu}_1$ -

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

$$u = 9.6917274\text{E}-006$$

$$\text{Mu} = 2.1970\text{E}+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } cu = 0.0144353$$

$$\text{we ((5.4c), TBDY) } = ase * sh_{min} * f_{ywe} / f_{ce} + \text{Min}(fx, fy) = 0.07473805$$

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

-----  
 $fx = 0.06888919$

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

$$af = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.008128$   
 $bw = 250.00$   
effective stress from (A.35),  $ff,e = 703.4155$

$fy = 0.06888919$   
Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
 $af = 0.24098246$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35),  $ff,e = 703.4155$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c$  = confinement factor = 1.0981

$y1 = 0.00124738$

$sh1 = 0.00431097$

$ft1 = 359.2441$

$fy1 = 299.3701$

$su1 = 0.00446911$

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

$lo/lo_{u,min} = lb/ld = 0.28304984$

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

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, ASCE41-17.

with  $fs1 = fs = 299.3701$

with  $Es1 = Es = 200000.00$

$y2 = 0.00124738$

$$sh2 = 0.00431097$$

$$ft2 = 359.2441$$

$$fy2 = 299.3701$$

$$su2 = 0.00446911$$

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

$$lo/lo_{min} = lb/lb_{min} = 0.28304984$$

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

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, ASCE41-17.

$$\text{with } fs2 = fs = 299.3701$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00124738$$

$$shv = 0.00431097$$

$$ftv = 359.2441$$

$$fyv = 299.3701$$

$$suv = 0.00446911$$

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

$$lo/lo_{min} = lb/ld = 0.28304984$$

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

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

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

For calculation of  $esuv_{nominal}$  and  $yv$ ,  $shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 299.3701$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d) * (fs1/fc) = 0.03714718$$

$$2 = Asl_{com}/(b*d) * (fs2/fc) = 0.0782342$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.06922883$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 21.96205$$

$$cc (5A.5, TBDY) = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = Asl_{ten}/(b*d) * (fs1/fc) = 0.04362424$$

$$2 = Asl_{com}/(b*d) * (fs2/fc) = 0.09187529$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08129972$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vsy2$  - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.17212448$$

$$Mu = MRc (4.14) = 2.1970E+008$$

$$u = su (4.1) = 9.6917274E-006$$

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

Lap Length:  $lb/ld = 0.28304984$

$$lb = 300.00$$

$$ld = 1059.884$$

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

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars:  $fy = 555.55$

$$fc' = 20.00, \text{ but } fc'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

e = 1.00  
cb = 25.00  
Ktr = 2.61799  
Atr = Min(Atr\_x,Atr\_y) = 157.0796  
where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis  
s = 150.00  
n = 16.00

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-----  
Calculation of Mu2+

-----  
-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:  
u = 1.1848408E-005  
Mu = 3.9843E+008

-----  
with full section properties:

b = 250.00  
d = 557.00  
d' = 43.00  
v = 0.0031899  
N = 8883.864  
fc = 20.00  
co (5A.5, TBDY) = 0.002  
Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.0144353$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\mu_c = 0.0144353$   
 $\mu_{cc}$  ((5.4c), TBDY) =  $\text{ase} * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$   
where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$   
 $a_f = 0.24098246$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 57233.333$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

-----  
 $f_y = 0.06888919$

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

$a_f = 0.24098246$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 0.00$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

-----  
R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

$\text{ase} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and

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

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and

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

equal to half the clear spacing between hoops.

AnoConf = 105733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00321875$

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

-----  
 $psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c = \text{confinement factor} = 1.0981$

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

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

$lo/lo_{min} = lb/l_d = 0.28304984$

$su_1 = 0.4 * esu_{1\_nominal} \text{ ((5.5), TBDY)} = 0.032$

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

For calculation of  $esu_{1\_nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

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

$lo/lo_{min} = lb/l_{b,min} = 0.28304984$

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

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  $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_2 = fs = 299.3701$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$su_v = 0.00446911$

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

$lo/lo_{min} = lb/l_d = 0.28304984$

$su_v = 0.4 * esu_{v\_nominal} \text{ ((5.5), TBDY)} = 0.032$

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

considering characteristic value  $fsy_v = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esu_{v\_nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered

characteristic value  $fsy_v = fsv/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fsv = fs = 299.3701$

with  $Esv = Es = 200000.00$

$1 = Asl,ten/(b \cdot d) \cdot (fs_1/fc) = 0.18776209$

$2 = Asl,com/(b \cdot d) \cdot (fs_2/fc) = 0.08915322$

$v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.16614919$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$fcc$  (5A.2, TBDY) = 21.96205

$cc$  (5A.5, TBDY) = 0.00298102

$c$  = confinement factor = 1.0981

$1 = Asl,ten/(b \cdot d) \cdot (fs_1/fc) = 0.26111925$

$2 = Asl,com/(b \cdot d) \cdot (fs_2/fc) = 0.12398468$

$v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.23106236$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y_2$  - LHS eq.(4.5) is not satisfied

--->

$v < vs,c$  - RHS eq.(4.5) is satisfied

--->

$su$  (4.8) = 0.32281672

$Mu = MRc$  (4.15) = 3.9843E+008

$u = su$  (4.1) = 1.1848408E-005

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

Lap Length:  $lb/ld = 0.28304984$

$lb = 300.00$

$ld = 1059.884$

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

= 1

$db = 18.00$

Mean strength value of all re-bars:  $fy = 555.55$

$fc' = 20.00$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 2.61799$

$Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$

where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

-----  
Calculation of  $Mu_2$ -

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

$u = 9.6917274E-006$

$Mu = 2.1970E+008$

-----  
with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$fc = 20.00$

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

Final value of  $cu$ :  $cu^* = \text{shear\_factor} \cdot \text{Max}(cu, cc) = 0.0144353$

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

From (5.4b), TBDY:  $c_u = 0.0144353$

$w_e$  ((5.4c), TBDY) =  $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

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

-----  
 $f_x = 0.06888919$

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

$af = 0.24098246$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $pf = 2tf / bw = 0.008128$

$bw = 250.00$

effective stress from (A.35),  $ff_e = 703.4155$

-----  
 $f_y = 0.06888919$

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

$af = 0.24098246$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $pf = 2tf / bw = 0.008128$

$bw = 250.00$

effective stress from (A.35),  $ff_e = 703.4155$

-----  
 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $p_{sh,x}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $p_{sh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$fy_{we} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c = \text{confinement factor} = 1.0981$

$y1 = 0.00124738$

$sh1 = 0.00431097$

$ft1 = 359.2441$

$fy1 = 299.3701$

$su1 = 0.00446911$

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

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

Shear\_factor = 1.00

lo/lou,min = lb/d = 0.28304984

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, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

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

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

Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

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, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

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

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

Shear\_factor = 1.00

lo/lou,min = lb/d = 0.28304984

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, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.03714718

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0782342

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06922883

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04362424

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09187529

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.08129972

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.17212448

Mu = MRc (4.14) = 2.1970E+008

u = su (4.1) = 9.6917274E-006

-----  
Calculation of ratio lb/d

Lap Length:  $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars:  $f_y = 555.55$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 150.00$

$n = 16.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1,  $V_{r1} = 424229.688$

$V_{r1} = V_{CoI} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{CoI0}$

$V_{CoI0} = 424229.688$

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

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs + f\*Vf'

where Vf is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 47.23669$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 93083.296$  is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.75$

$V_{s2} = 223399.91$  is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.3125$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 293495.545$

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

orientation 1:  $\theta = 45^\circ$  and  $\theta = 90^\circ$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 557.00

$f_{fe}$  ((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:  $V_s + V_f \leq 356502.845$   
 $b_w$  = 250.00

Calculation of Shear Strength at edge 2,  $V_{r2}$  = 424229.688  
 $V_{r2} = V_{CoI}$  ((10.3), ASCE 41-17) =  $k_n I V_{CoI0}$   
 $V_{CoI0}$  = 424229.688  
 $k_n I$  = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)  
 $f_c'$  = 20.00, but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd$  = 4.00  
 $\mu_u$  = 47.23667  
 $V_u$  = 0.00016213  
 $d$  =  $0.8 \cdot h$  = 480.00  
 $N_u$  = 8883.864  
 $A_g$  = 150000.00  
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1}$  = 93083.296 is calculated for section web, with:

$d$  = 200.00  
 $A_v$  = 157079.633  
 $f_y$  = 444.44  
 $s$  = 150.00

$V_{s1}$  is multiplied by  $Col1$  = 1.00

$s/d$  = 0.75

$V_{s2}$  = 223399.91 is calculated for section flange, with:

$d$  = 480.00  
 $A_v$  = 157079.633  
 $f_y$  = 444.44  
 $s$  = 150.00

$V_{s2}$  is multiplied by  $Col2$  = 1.00

$s/d$  = 0.3125

$V_f$  ((11-3)-(11.4), ACI 440) = 293495.545

$f$  = 0.95, for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 557.00

$f_{fe}$  ((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:  $V_s + V_f \leq 356502.845$

$b_w$  = 250.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1  
At local axis: 2

Integration Section: (b)  
Section Type: rdcs

### Constant Properties

Knowledge Factor,  $\gamma = 0.77$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

### Stepwise Properties

Bending Moment,  $M = -122390.945$

Shear Force,  $V_2 = 4259.045$

Shear Force,  $V_3 = -148.2786$

Axial Force,  $F = -9662.362$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression:  $A_{sl,c} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1746.726$

-Compression:  $A_{sl,com} = 829.3805$

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

Mean Diameter of Tension Reinforcement,  $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = \gamma \cdot u = 0.00148279$

$u = \gamma \cdot p = 0.0019257$

- Calculation of  $\gamma$  -

$\gamma = (M \cdot L_s / 3) / E_{eff} = 0.0019257$  ((4.29), Biskinis Phd))

$M \gamma = 2.9341E+008$

$L_s = M / V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 825.4121

From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$

factor = 0.30

Ag = 237500.00  
fc' = 20.00  
N = 9662.362  
Ec\*Ig = 1.3974E+014

-----  
-----  
Calculation of Yielding Moment My

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

-----  
y = Min(  $y_{ten}$ ,  $y_{com}$  )  
 $y_{ten} = 4.0518245E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25*f_y*(l_b/d)^{2/3}) = 277.9106$   
d = 557.00  
y = 0.3842998  
A = 0.02984946  
B = 0.0192317  
with pt = 0.01254381  
pc = 0.00595605  
pv = 0.01109992  
N = 9662.362  
b = 250.00  
" = 0.07719928  
 $y_{comp} = 8.1947240E-006$   
with  $f_c^*$  (12.3, (ACI 440)) = 20.42407  
fc = 20.00  
fl = 0.62098351  
b = bmax = 600.00  
h = hmax = 600.00  
Ag = 237500.00  
g = pt + pc + pv = 0.02959978  
rc = 40.00  
Ae/Ac = 0.21783041  
Effective FRP thickness,  $t_f = NL*t*\text{Cos}(b1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
fu = 0.01  
Ef = 64828.00  
Ec = 21019.039  
y = 0.38318842  
A = 0.02940142  
B = 0.01898202  
with Es = 200000.00

-----  
-----  
Calculation of ratio lb/d

-----  
Lap Length:  $l_d/d_{min} = 0.3538123$

lb = 300.00

ld = 847.9072

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

= 1

db = 18.00

Mean strength value of all re-bars:  $f_y = 444.44$

fc' = 20.00, but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.61799

Atr = Min(Atr\_x, Atr\_y) = 157.0796

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

s = 150.00

n = 16.00

- Calculation of  $p$  -

From table 10-8:  $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/l_d \geq 1$   
shear control ratio  $V_{yE}/V_{CoIE} = 0.62612363$

$d = 557.00$

$s = 0.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1460.00$ , is the total Length of all stirrups parallel to loading (shear) direction

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

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

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

$NUD = 9662.362$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} = 0.00$

$p_l = \text{Area\_Tot\_Long\_Rein}/(b*d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 7

column C1, Floor 1

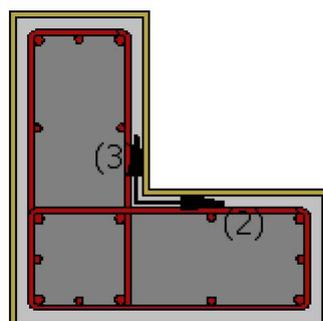
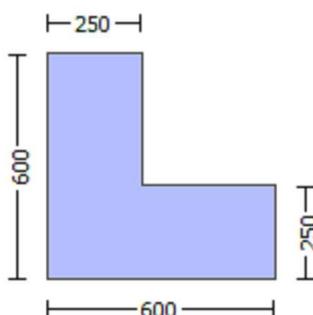
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rdcs

### Constant Properties

Knowledge Factor,  $\gamma = 0.77$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

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

Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

### Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -320830.403$

Shear Force,  $V_a = 148.2786$

EDGE -B-

Bending Moment,  $M_b = -122390.945$

Shear Force,  $V_b = -148.2786$

BOTH EDGES

Axial Force,  $F = -9662.362$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl} = 0.00$

-Compression:  $A_{sc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1746.726$

-Compression:  $A_{sl,com} = 829.3805$

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

Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 339075.376$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI0} = 440357.631$   
 $V_{CoI} = 440357.631$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 1.2067023E-005$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs +  $\phi \cdot V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)  
 $f_c' = 16.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 122390.945$   
 $V_u = 148.2786$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 9662.362$   
 $A_g = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 284837.734$   
 where:  
 $V_{s1} = 201061.93$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $CoI1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 83775.804$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $CoI2 = 1.00$   
 $s/d = 0.75$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 293495.545  
 $\phi = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin^2 + \cos^2$  is replaced with  $(\cot^2 + \csc^2) \sin^2 \alpha$  which is more a generalised expression,  
 where  $\alpha$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\alpha)$ , 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:  $\alpha = 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 557.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 318865.838$   
 $b_w = 250.00$

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

- Calculation of  $\phi / y$  for END B -  
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation  $\phi = 2.3237426E-008$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.0019257$  ((4.29), Biskinis Phd))  
 $M_y = 2.9341E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 825.4121  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$

factor = 0.30  
Ag = 237500.00  
fc' = 20.00  
N = 9662.362  
Ec\*Ig = 1.3974E+014

-----  
-----  
Calculation of Yielding Moment My

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

-----  
y = Min(  $y_{ten}$ ,  $y_{com}$  )  
 $y_{ten} = 4.0518245E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25*f_y*(l_b/d)^{2/3}) = 277.9106$   
d = 557.00  
y = 0.3842998  
A = 0.02984946  
B = 0.0192317  
with pt = 0.01254381  
pc = 0.00595605  
pv = 0.01109992  
N = 9662.362  
b = 250.00  
" = 0.07719928  
 $y_{comp} = 8.1947240E-006$   
with  $fc^*$  (12.3, (ACI 440)) = 20.42407  
fc = 20.00  
fl = 0.62098351  
b = bmax = 600.00  
h = hmax = 600.00  
Ag = 237500.00  
g = pt + pc + pv = 0.02959978  
rc = 40.00  
Ae/Ac = 0.21783041  
Effective FRP thickness,  $t_f = NL*t*\text{Cos}(b1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
fu = 0.01  
Ef = 64828.00  
Ec = 21019.039  
y = 0.38318842  
A = 0.02940142  
B = 0.01898202  
with Es = 200000.00

-----  
-----  
Calculation of ratio  $l_b/d$

-----  
Lap Length:  $l_d/l_d, \text{min} = 0.3538123$

$l_b = 300.00$

$l_d = 847.9072$

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

= 1

db = 18.00

Mean strength value of all re-bars:  $f_y = 444.44$

$fc' = 20.00$ , but  $fc^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.61799

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

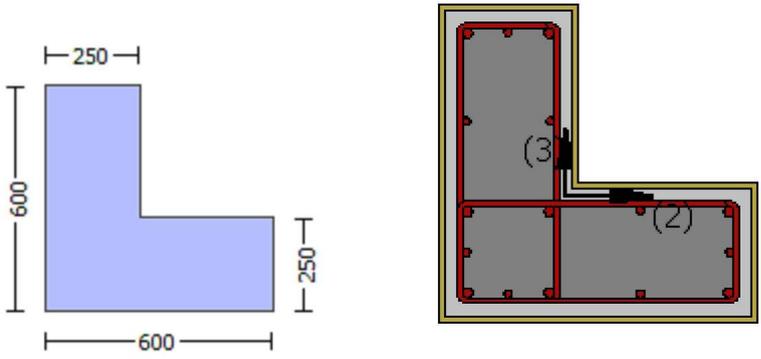
s = 150.00

n = 16.00

End Of Calculation of Shear Capacity for element: column LC1 of floor 1  
 At local axis: 3  
 Integration Section: (b)

**Calculation No. 8**

column C1, Floor 1  
 Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)  
 Analysis: Uniform +X  
 Check: Chord rotation capacity (  $\theta$  )  
 Edge: End  
 Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At Shear local axis: 3  
 (Bending local axis: 2)  
 Section Type: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$

#####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$

#####  
 Max Height,  $H_{max} = 600.00$   
 Min Height,  $H_{min} = 250.00$   
 Max Width,  $W_{max} = 600.00$   
 Min Width,  $W_{min} = 250.00$   
 Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.0981  
Element Length, L = 3000.00  
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o$  = 300.00  
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t$  = 1.016  
Tensile Strength,  $f_{fu}$  = 1055.00  
Tensile Modulus,  $E_f$  = 64828.00  
Elongation,  $e_{fu}$  = 0.01  
Number of directions, NoDir = 1  
Fiber orientations,  $b_i$ : 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

-----  
Stepwise Properties  
-----

At local axis: 3  
EDGE -A-  
Shear Force,  $V_a$  = 0.00016213  
EDGE -B-  
Shear Force,  $V_b$  = -0.00016213  
BOTH EDGES  
Axial Force,  $F$  = -8883.864  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st}$  = 0.00  
-Compression:  $A_{sc}$  = 4121.77  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten}$  = 1746.726  
-Compression:  $A_{st,com}$  = 829.3805  
-Middle:  $A_{st,mid}$  = 1545.664  
-----  
-----

Calculation of Shear Capacity ratio ,  $V_e/V_r$  = 0.62612363  
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$   
with  
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.9843E+008$   
 $\mu_{1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
which is defined for the static loading combination  
 $\mu_{1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.9843E+008$   
 $\mu_{2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
which is defined for the the static loading combination  
 $\mu_{2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment  
direction which is defined for the the static loading combination

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

-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu = 1.1848408E-005$   
 $\mu_u = 3.9843E+008$   
-----

with full section properties:  
 $b = 250.00$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

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

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$c = \text{confinement factor} = 1.0981$   
 $y1 = 0.00124738$   
 $sh1 = 0.00431097$   
 $ft1 = 359.2441$   
 $fy1 = 299.3701$   
 $su1 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.28304984$   
 $su1 = 0.4 * esu1\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
 For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs1 = fs = 299.3701$   
 with  $Es1 = Es = 200000.00$   
 $y2 = 0.00124738$   
 $sh2 = 0.00431097$   
 $ft2 = 359.2441$   
 $fy2 = 299.3701$   
 $su2 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/lb,min = 0.28304984$   
 $su2 = 0.4 * esu2\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , 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, ASCE41-17.  
 with  $fs2 = fs = 299.3701$   
 with  $Es2 = Es = 200000.00$   
 $yv = 0.00124738$   
 $shv = 0.00431097$   
 $ftv = 359.2441$   
 $fyv = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.28304984$   
 $suv = 0.4 * esuv\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 299.3701$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.18776209$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.08915322$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.16614919$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $fcc (5A.2, \text{TBDY}) = 21.96205$   
 $cc (5A.5, \text{TBDY}) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.26111925$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.12398468$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.23106236$   
 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) = 0.32281672  
Mu = MRc (4.15) = 3.9843E+008  
u = su (4.1) = 1.1848408E-005

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Lap Length: lb/l<sub>d</sub> = 0.28304984

lb = 300.00

l<sub>d</sub> = 1059.884

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

= 1

db = 18.00

Mean strength value of all re-bars: f<sub>y</sub> = 555.55

fc' = 20.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K<sub>tr</sub> = 2.61799

A<sub>tr</sub> = Min(A<sub>tr\_x</sub>, A<sub>tr\_y</sub>) = 157.0796

where A<sub>tr\_x</sub>, A<sub>tr\_y</sub> are the sum of the area of all stirrup legs along X and Y local axis

s = 150.00

n = 16.00

-----  
Calculation of Mu1-

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

u = 9.6917274E-006

Mu = 2.1970E+008

-----  
with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.0144353

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

From (5.4b), TBDY: cu = 0.0144353

we ((5.4c), TBDY) = ase\* sh,min\*f<sub>ywe</sub>/f<sub>ce</sub>+Min( f<sub>x</sub>, f<sub>y</sub>) = 0.07473805

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

-----  
f<sub>x</sub> = 0.06888919

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

af = 0.24098246

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 57233.333

bmax = 600.00

hmax = 600.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128

bw = 250.00

effective stress from (A.35), ff,e = 703.4155

-----  
f<sub>y</sub> = 0.06888919

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

af = 0.24098246

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 0.00

bmax = 600.00

hmax = 600.00  
From EC8 A.4.3(6),  $pf = 2tf/bw = 0.008128$   
bw = 250.00  
effective stress from (A.35),  $ff,e = 703.4155$

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

$ase = \text{Max}((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}} * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$   
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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along Y) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along X) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

s = 150.00  
 $f_{ywe} = 555.55$   
fce = 20.00

From ((5.A.5), TBDY), TBDY:  $cc = 0.00298102$   
c = confinement factor = 1.0981

$y1 = 0.00124738$   
 $sh1 = 0.00431097$   
ft1 = 359.2441  
 $fy1 = 299.3701$   
 $su1 = 0.00446911$

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

$l_o/l_{o,min} = l_b/l_d = 0.28304984$

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

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

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

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs1 = fs = 299.3701$

with  $Es1 = Es = 200000.00$

$y2 = 0.00124738$   
 $sh2 = 0.00431097$   
ft2 = 359.2441  
 $fy2 = 299.3701$   
 $su2 = 0.00446911$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$

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

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, ASCE41-17.

with  $fs_2 = fs = 299.3701$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$s_{uv} = 0.00446911$

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

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

Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.28304984$

$s_{uv} = 0.4 \cdot es_{uv\_nominal}$  ((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, ASCE41-17.

with  $fs_v = fs = 299.3701$

with  $Es_v = Es = 200000.00$

1 =  $As_{l,ten}/(b \cdot d) \cdot (fs_1/fc) = 0.03714718$

2 =  $As_{l,com}/(b \cdot d) \cdot (fs_2/fc) = 0.0782342$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/fc) = 0.06922883$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 21.96205

$cc$  (5A.5, TBDY) = 0.00298102

$c$  = confinement factor = 1.0981

1 =  $As_{l,ten}/(b \cdot d) \cdot (fs_1/fc) = 0.04362424$

2 =  $As_{l,com}/(b \cdot d) \cdot (fs_2/fc) = 0.09187529$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/fc) = 0.08129972$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$s_u$  (4.9) = 0.17212448

$\mu_u = MR_c$  (4.14) = 2.1970E+008

$u = s_u$  (4.1) = 9.6917274E-006

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

-----  
Lap Length:  $lb/ld = 0.28304984$

$lb = 300.00$

$ld = 1059.884$

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

= 1

$db = 18.00$

Mean strength value of all re-bars:  $f_y = 555.55$

$f'_c = 20.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 150.00$

$n = 16.00$

-----  
Calculation of Mu2+  
-----

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

$$\mu = 1.1848408E-005$$

$$Mu = 3.9843E+008$$

-----

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e^* s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

-----

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

-----

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

-----

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,\min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

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

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.00124738

sh1 = 0.00431097

ft1 = 359.2441

fy1 = 299.3701

su1 = 0.00446911

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

lo/lou,min = lb/d = 0.28304984

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, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

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

lo/lou,min = lb/lb,min = 0.28304984

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, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

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

lo/lou,min = lb/d = 0.28304984

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, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.18776209

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.08915322

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.16614919

and confined core properties:

b = 190.00

d = 527.00

$d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$   
 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  
 --->  
 $su (4.8) = 0.32281672$   
 $Mu = MR_c (4.15) = 3.9843E+008$   
 $u = su (4.1) = 1.1848408E-005$

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

Lap Length:  $l_b/l_d = 0.28304984$   
 $l_b = 300.00$   
 $l_d = 1059.884$   
 Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 18.00$   
 Mean strength value of all re-bars:  $f_y = 555.55$   
 $f_c' = 20.00$ , but  $f_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.61799$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$   
 where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = 150.00$   
 $n = 16.00$

-----  
 Calculation of  $Mu_2$ -  
 -----

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 9.6917274E-006$   
 $Mu = 2.1970E+008$   
 -----

with full section properties:

$b = 600.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00132912$   
 $N = 8883.864$   
 $f_c = 20.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.0144353$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.0144353$   
 $w_e ((5.4c), TBDY) = a_s * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$   
 where  $f = af * pf * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)  
 -----  
 $f_x = 0.06888919$   
 Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
 $af = 0.24098246$   
 with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

bmax = 600.00  
hmax = 600.00  
From EC8 A 4.4.3(6),  $pf = 2tf/bw = 0.008128$   
bw = 250.00  
effective stress from (A.35),  $ff,e = 703.4155$

-----  
fy = 0.06888919  
Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
af = 0.24098246  
with Unconfined area =  $((bmax-2R)^2 + (hmax-2R)^2)/3 = 0.00$   
bmax = 600.00  
hmax = 600.00  
From EC8 A 4.4.3(6),  $pf = 2tf/bw = 0.008128$   
bw = 250.00  
effective stress from (A.35),  $ff,e = 703.4155$

-----  
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 =  $Max(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.21805635$   
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,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.  
Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.  
AnoConf = 105733.333 is the unconfined core area which is equal to  $bi^2/6$  as defined at (A.2).  
psh,min =  $Min(psh,x, psh,y) = 0.00321875$   
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
psh,x ((5.4d), TBDY) =  $Lstir * Astir / (Asec * s) = 0.00321875$   
Lstir (Length of stirrups along Y) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

-----  
psh,y ((5.4d), TBDY) =  $Lstir * Astir / (Asec * s) = 0.00321875$   
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

-----  
s = 150.00  
fywe = 555.55  
fce = 20.00  
From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$   
c = confinement factor = 1.0981  
y1 = 0.00124738  
sh1 = 0.00431097  
ft1 = 359.2441  
fy1 = 299.3701  
su1 = 0.00446911  
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
lo/lou,min =  $lb/d = 0.28304984$   
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, ASCE41-17.  
with  $fs1 = fs = 299.3701$

with  $E_{s1} = E_s = 200000.00$   
 $y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $fy_2 = 299.3701$   
 $su_2 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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, ASCE41-17.  
 with  $fs_2 = fs = 299.3701$   
 with  $E_{s2} = E_s = 200000.00$   
 $y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $fy_v = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $l_o/l_{o,min} = l_b/l_d = 0.28304984$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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, ASCE41-17.  
 with  $fsv = fs = 299.3701$   
 with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.03714718$   
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.0782342$   
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.06922883$   
 and confined core properties:  
 $b = 540.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.04362424$   
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.09187529$   
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.08129972$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_s, y_2$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.17212448$   
 $Mu = MRc (4.14) = 2.1970E+008$   
 $u = su (4.1) = 9.6917274E-006$

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

Lap Length:  $l_b/l_d = 0.28304984$   
 $l_b = 300.00$   
 $l_d = 1059.884$   
 Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 18.00$   
 Mean strength value of all re-bars:  $fy = 555.55$   
 $fc' = 20.00$ , but  $fc^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 2.61799$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = 150.00$   
 $n = 16.00$

-----  
 Calculation of Shear Strength  $Vr = \text{Min}(Vr1, Vr2) = 424229.688$   
 -----

Calculation of Shear Strength at edge 1,  $Vr1 = 424229.688$

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

$VCol0 = 424229.688$

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

-----  
 NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf'  
 where Vf is the contribution of FRPs (11.3), ACI 440).

-----  
 $= 1$  (normal-weight concrete)

$fc' = 20.00$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 47.24078$

$Vu = 0.00016213$

$d = 0.8 * h = 480.00$

$Nu = 8883.864$

$Ag = 150000.00$

From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 316483.206$

where:

$Vs1 = 223399.91$  is calculated for section web, with:

$d = 480.00$

$Av = 157079.633$

$fy = 444.44$

$s = 150.00$

$Vs1$  is multiplied by  $Col1 = 1.00$

$s/d = 0.3125$

$Vs2 = 93083.296$  is calculated for section flange, with:

$d = 200.00$

$Av = 157079.633$

$fy = 444.44$

$s = 150.00$

$Vs2$  is multiplied by  $Col2 = 1.00$

$s/d = 0.75$

$Vf$  ((11-3)-(11.4), ACI 440) =  $293495.545$

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

$dfv = d$  (figure 11.2, ACI 440) =  $557.00$

$ffe$  ((11-5), ACI 440) =  $259.312$

$Ef = 64828.00$

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

with  $fu = 0.01$

From (11-11), ACI 440:  $Vs + Vf \leq 356502.845$

$bw = 250.00$

-----  
 Calculation of Shear Strength at edge 2,  $Vr2 = 424229.688$   
 -----

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

$$VCol0 = 424229.688$$

$$knl = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf'  
where Vf is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$fc' = 20.00, \text{ but } fc^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$Mu = 47.24081$$

$$Vu = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$Nu = 8883.864$$

$$Ag = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } Vs = Vs1 + Vs2 = 316483.206$$

where:

Vs1 = 223399.91 is calculated for section web, with:

$$d = 480.00$$

$$Av = 157079.633$$

$$fy = 444.44$$

$$s = 150.00$$

Vs1 is multiplied by Col1 = 1.00

$$s/d = 0.3125$$

Vs2 = 93083.296 is calculated for section flange, with:

$$d = 200.00$$

$$Av = 157079.633$$

$$fy = 444.44$$

$$s = 150.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.75$$

$$Vf \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$$

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

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

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

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

This later relation, considered as a function  $Vf(\alpha)$ , 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.

$$\text{orientation 1: } \alpha = \alpha_1 + 90^\circ = 90.00$$

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

$$\text{total thickness per orientation, } tf1 = NL * t / NoDir = 1.016$$

$$dfv = d \text{ (figure 11.2, ACI 440)} = 557.00$$

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

$$Ef = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } Vs + Vf \leq 356502.845$$

$$bw = 250.00$$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\phi = 0.77$

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

Consequently:

Existing material of Secondary Member: Concrete Strength,  $fc = fcm = 20.00$

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

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

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

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties

-----  
At local axis: 2

EDGE -A-

Shear Force,  $V_a = 0.00016213$

EDGE -B-

Shear Force,  $V_b = -0.00016213$

BOTH EDGES

Axial Force,  $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression:  $A_{sl,c} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1746.726$

-Compression:  $A_{sl,com} = 829.3805$

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

-----  
-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.62612363$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.9843E+008$

$M_{u1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.9843E+008$

$M_{u2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment

direction which is defined for the the static loading combination

Calculation of  $\mu_{1+}$

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

$$\mu = 1.1848408E-005$$

$$\mu_{1+} = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

Lstir (Length of stirrups along Y) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875  
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00  
fywe = 555.55  
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102  
c = confinement factor = 1.0981

y1 = 0.00124738  
sh1 = 0.00431097  
ft1 = 359.2441  
fy1 = 299.3701  
su1 = 0.00446911

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

lo/lou,min = lb/d = 0.28304984

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

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

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

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738  
sh2 = 0.00431097  
ft2 = 359.2441  
fy2 = 299.3701  
su2 = 0.00446911

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

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

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

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738  
shv = 0.00431097  
ftv = 359.2441  
fyv = 299.3701  
suv = 0.00446911

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

lo/lou,min = lb/d = 0.28304984

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

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

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.18776209

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.08915322

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.16614919

and confined core properties:

$b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$   
 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  
 --->  
 $su (4.8) = 0.32281672$   
 $Mu = MRc (4.15) = 3.9843E+008$   
 $u = su (4.1) = 1.1848408E-005$

-----  
 Calculation of ratio  $l_b/d$   
 -----

Lap Length:  $l_b/d = 0.28304984$   
 $l_b = 300.00$   
 $l_d = 1059.884$   
 Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 18.00$   
 Mean strength value of all re-bars:  $f_y = 555.55$   
 $f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.61799$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$   
 where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = 150.00$   
 $n = 16.00$

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

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 9.6917274E-006$   
 $Mu = 2.1970E+008$

-----  
 with full section properties:

$b = 600.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00132912$   
 $N = 8883.864$   
 $f_c = 20.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.0144353$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.0144353$   
 $we ((5.4c), TBDY) = ase * sh, \min * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$   
 where  $f = af * pf * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)  
 -----  
 $f_x = 0.06888919$   
 Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

af = 0.24098246  
with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$   
bmax = 600.00  
hmax = 600.00  
From EC8 A.4.4.3(6), pf =  $2t_f/b_w = 0.008128$   
bw = 250.00  
effective stress from (A.35), ff,e = 703.4155

fy = 0.06888919  
Expression ((15B.6), TBDY) is modified as af =  $1 - (\text{Unconfined area})/(\text{total area})$   
af = 0.24098246

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$   
bmax = 600.00  
hmax = 600.00  
From EC8 A.4.4.3(6), pf =  $2t_f/b_w = 0.008128$   
bw = 250.00  
effective stress from (A.35), ff,e = 703.4155

R = 40.00  
Effective FRP thickness, tf =  $NL*t*\text{Cos}(b_1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015

ase =  $\text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

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,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 105733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min =  $\text{Min}(psh,x, psh,y) = 0.00321875$

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

psh,x ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$   
Lstir (Length of stirrups along Y) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$   
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00  
fywe = 555.55  
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102  
c = confinement factor = 1.0981

y1 = 0.00124738  
sh1 = 0.00431097  
ft1 = 359.2441  
fy1 = 299.3701  
su1 = 0.00446911

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

lo/lou,min =  $l_b/l_d = 0.28304984$

su1 =  $0.4*es_{u1\_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $es_{u1\_nominal} = 0.08$ ,

For calculation of  $es_{u1\_nominal}$  and y1, sh1, ft1, fy1, it is considered characteristic value  $fs_{y1} = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

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

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

Shear\_factor = 1.00

$lo/lo_{min} = lb/lb_{min} = 0.28304984$

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

From table 5A.1, TBDY:  $esu_{2\_nominal} = 0.08$ ,

For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_2 = fs = 299.3701$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$su_v = 0.00446911$

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

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

Shear\_factor = 1.00

$lo/lo_{min} = lb/ld = 0.28304984$

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

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

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

For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fsv = fs = 299.3701$

with  $Esv = Es = 200000.00$

$1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.03714718$

$2 = Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.0782342$

$v = Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.06922883$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, \text{TBDY}) = 21.96205$

$cc (5A.5, \text{TBDY}) = 0.00298102$

$c = \text{confinement factor} = 1.0981$

$1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.04362424$

$2 = Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.09187529$

$v = Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.08129972$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.17212448$

$Mu = MRc (4.14) = 2.1970E+008$

$u = su (4.1) = 9.6917274E-006$

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

-----  
Lap Length:  $lb/ld = 0.28304984$

$lb = 300.00$

$ld = 1059.884$

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

= 1

$db = 18.00$

Mean strength value of all re-bars:  $f_y = 555.55$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 150.00$

$n = 16.00$

-----  
-----  
-----  
Calculation of  $\mu_{2+}$   
-----

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

$\mu = 1.1848408E-005$

$\mu_{2+} = 3.9843E+008$

-----  
with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

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

Final value of  $\mu_{cu}$ :  $\mu_{cu}^* = \text{shear\_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.0144353$

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

From (5.4b), TBDY:  $\mu_{cu} = 0.0144353$

where  $\mu_{cu}$  ((5.4c), TBDY) =  $\alpha_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

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

-----  
 $f_x = 0.06888919$

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

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{fe} = 703.4155$

-----  
 $f_y = 0.06888919$

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

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{fe} = 703.4155$

-----  
 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$

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,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 105733.333 is the unconfined core area which is equal to  $b^2/6$  as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00321875

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

psh,x ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.00124738

sh1 = 0.00431097

ft1 = 359.2441

fy1 = 299.3701

su1 = 0.00446911

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

lo/lou,min = lb/lb = 0.28304984

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, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

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

lo/lou,min = lb/lb,min = 0.28304984

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, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

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

lo/lou,min = lb/lb = 0.28304984

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $e_{sv\_nominal} = 0.08$ ,  
considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $e_{sv\_nominal}$  and  $\gamma_v$ ,  $sh_v, ft_v, f_{y_v}$ , it is considered  
characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $\gamma_1$ ,  $sh_1, ft_1, f_{y_1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
with  $f_{sv} = f_s = 299.3701$   
with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.18776209$   
 $2 = A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08915322$   
 $v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.16614919$

and confined core properties:

$b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} \text{ (5A.2, TBDY)} = 21.96205$   
 $cc \text{ (5A.5, TBDY)} = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.26111925$   
 $2 = A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12398468$   
 $v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.23106236$

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

---->  
 $\mu_u \text{ (4.8)} = 0.32281672$   
 $\mu_u = M_{Rc} \text{ (4.15)} = 3.9843E+008$   
 $u = \mu_u \text{ (4.1)} = 1.1848408E-005$

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

-----  
Lap Length:  $l_b/l_d = 0.28304984$

$l_b = 300.00$   
 $l_d = 1059.884$

Calculation of  $l_b, \text{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

$d_b = 18.00$   
Mean strength value of all re-bars:  $f_y = 555.55$   
 $f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $c_b = 25.00$   
 $K_{tr} = 2.61799$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$   
where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = 150.00$   
 $n = 16.00$

-----  
Calculation of  $\mu_u$

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

$u = 9.6917274E-006$   
 $\mu_u = 2.1970E+008$

-----  
with full section properties:

$b = 600.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00132912$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$\text{we (5.4c), TBDY) } = a_s e^* \text{ sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,\min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1460.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$ft1 = 359.2441$   
 $fy1 = 299.3701$   
 $su1 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/d = 0.28304984$   
 $su1 = 0.4*esu1\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE41-17.  
 with  $fs1 = fs = 299.3701$   
 with  $Es1 = Es = 200000.00$   
 $y2 = 0.00124738$   
 $sh2 = 0.00431097$   
 $ft2 = 359.2441$   
 $fy2 = 299.3701$   
 $su2 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/lb,min = 0.28304984$   
 $su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE41-17.  
 with  $fs2 = fs = 299.3701$   
 with  $Es2 = Es = 200000.00$   
 $yv = 0.00124738$   
 $shv = 0.00431097$   
 $ftv = 359.2441$   
 $fyv = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/d = 0.28304984$   
 $suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$   
 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, ASCE41-17.  
 with  $fsv = fs = 299.3701$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883$   
 and confined core properties:  
 $b = 540.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.17212448$   
 $Mu = MRc (4.14) = 2.1970E+008$

$$u = s_u(4.1) = 9.6917274E-006$$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.28304984$

$$l_b = 300.00$$

$$l_d = 1059.884$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1,  $V_{r1} = 424229.688$

$$V_{r1} = V_{Co1} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Co10}$$

$$V_{Co10} = 424229.688$$

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

NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_{s+} f^* V_f$ '

where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 47.23669$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 316483.206$$

where:

$V_{s1} = 93083.296$  is calculated for section web, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$$s/d = 0.75$$

$V_{s2} = 223399.91$  is calculated for section flange, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$$s/d = 0.3125$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$$

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

$w_f/s_f = 1$  (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  $\alpha$  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:  $\theta_1 = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 557.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 356502.845$   
 $b_w = 250.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 424229.688$   
 $V_{r2} = V_{CoI0}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{CoI0}$   
 $V_{CoI0} = 424229.688$   
 $k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s$ ' 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)  
 $f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 47.23667$   
 $\nu_u = 0.00016213$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 8883.864$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$   
where:

$V_{s1} = 93083.296$  is calculated for section web, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.75$

$V_{s2} = 223399.91$  is calculated for section flange, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.3125$

$V_f$  ((11-3)-(11.4), ACI 440) = 293495.545  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).

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

This later relation, considered as a function  $V_f(\theta, \alpha)$ , is implemented for every different fiber orientation  $a_i$ ,  
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,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 557.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 356502.845$   
 $b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rclcs

#### Constant Properties

Knowledge Factor,  $\gamma = 0.77$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

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

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

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 164093.879$

Shear Force,  $V_2 = 4259.045$

Shear Force,  $V_3 = -148.2786$

Axial Force,  $F = -9662.362$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression:  $A_{sl,c} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1746.726$

-Compression:  $A_{sl,com} = 829.3805$

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

Mean Diameter of Tension Reinforcement,  $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = \gamma \cdot u = 0.00053893$

$u = \gamma \cdot p = 0.0006999$

- Calculation of  $\gamma$  -

$\gamma = (M_y \cdot L_s / 3) / E_{eff} = 0.0006999 ((4.29), \text{Biskinis Phd})$

$M_y = 2.9341E+008$   
 $L_s = M/V$  (with  $L_s > 0.1*L$  and  $L_s < 2*L$ ) = 300.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 4.1921E+013$   
factor = 0.30  
Ag = 237500.00  
fc' = 20.00  
N = 9662.362  
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.0518245E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 277.9106$   
d = 557.00  
y = 0.3842998  
A = 0.02984946  
B = 0.0192317  
with pt = 0.01254381  
pc = 0.00595605  
pv = 0.01109992  
N = 9662.362  
b = 250.00  
" = 0.07719928  
 $y_{comp} = 8.1947240E-006$   
with fc' (12.3, (ACI 440)) = 20.42407  
fc = 20.00  
fl = 0.62098351  
b = bmax = 600.00  
h = hmax = 600.00  
Ag = 237500.00  
g = pt + pc + pv = 0.02959978  
rc = 40.00  
Ae/Ac = 0.21783041  
Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$   
effective strain from (12.5) and (12.12),  $e_{fe} = 0.004$   
fu = 0.01  
Ef = 64828.00  
Ec = 21019.039  
y = 0.38318842  
A = 0.02940142  
B = 0.01898202  
with Es = 200000.00

Calculation of ratio  $I_b / I_d$

Lap Length:  $I_d / I_d, \text{min} = 0.3538123$   
lb = 300.00  
ld = 847.9072  
Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1  
db = 18.00  
Mean strength value of all re-bars:  $f_y = 444.44$   
fc' = 20.00, but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
t = 1.00  
s = 0.80  
e = 1.00  
cb = 25.00  
Ktr = 2.61799  
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$   
where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

s = 150.00  
n = 16.00

- Calculation of  $\rho$  -

From table 10-8:  $\rho = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/d \geq 1$   
shear control ratio  $V_y E / V_{CoI} E = 0.62612363$

d = 557.00

s = 0.00

$t = A_v / (b w^* s) + 2^* t_f / b w^* (f_{fe} / f_s) = A_v^* L_{stir} / (A_g^* s) + 2^* t_f / b w^* (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1460.00$ , is the total Length of all stirrups parallel to loading (shear) direction

The term  $2^* t_f / b w^* (f_{fe} / f_s)$  is implemented to account for FRP contribution

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

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

$N_{UD} = 9662.362$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area\_Tot\_Long\_Rein} / (b^* d) = 0.02959978$

b = 250.00

d = 557.00

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 9

column C1, Floor 1

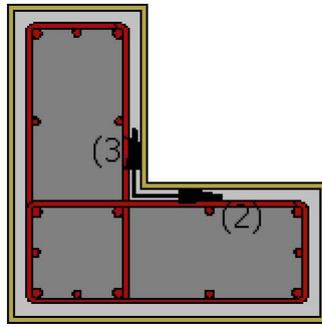
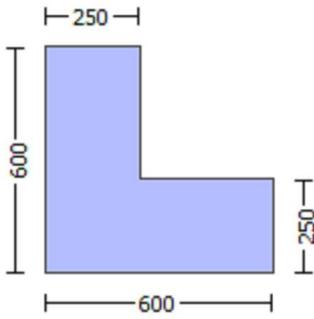
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rdcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

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

Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -1.0749E+007$

Shear Force,  $V_a = -3536.316$

EDGE -B-

Bending Moment,  $M_b = 136240.323$

Shear Force,  $V_b = 3536.316$

BOTH EDGES

Axial Force,  $F = -9530.256$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{s,ten} = 1746.726$

-Compression:  $A_{s,com} = 829.3805$

-Middle:  $A_{s,mid} = 1545.664$

Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 292291.023$

$V_n$  ((10.3), ASCE 41-17) =  $k_n \phi V_{CoI} = 379598.731$

$V_{CoI} = 379598.731$

$k_n = 1.00$

displacement\_ductility\_demand = 0.01483887

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+  $\phi V_f$ '  
where  $V_f$  is the contribution of FRPs ((11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 16.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.0749E+007$

$V_u = 3536.316$

$d = 0.8 \cdot h = 480.00$

$N_u = 9530.256$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 284837.734$

where:

$V_{s1} = 83775.804$  is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$

$V_{s1}$  is multiplied by  $\phi_{Col1} = 1.00$

$s/d = 0.75$

$V_{s2} = 201061.93$  is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$

$V_{s2}$  is multiplied by  $\phi_{Col2} = 1.00$

$s/d = 0.3125$

$V_f$  ((11-3)-(11.4), ACI 440) = 293495.545

$\phi = 0.95$ , for fully-wrapped sections

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

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

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

orientation 1:  $\theta = 45^\circ + 90^\circ = 135^\circ$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 557.00

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

$E_f = 64828.00$

$\phi_e = 0.004$ , from (11.6a), ACI 440

with  $\phi_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 318865.838$

$b_w = 250.00$

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 = 0.00010522  
 $y = (M_y * L_s / 3) / E_{eff} = 0.00709067$  ((4.29), Biskinis Phd)  
 $M_y = 2.9338E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3039.544  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 4.1921E+013$   
factor = 0.30  
 $A_g = 237500.00$   
 $f_c' = 20.00$   
 $N = 9530.256$   
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment  $M_y$

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

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.0516275E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 277.9106$   
 $d = 557.00$   
 $y = 0.38426988$   
 $A = 0.02984605$   
 $B = 0.01922829$   
with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9530.256$   
 $b = 250.00$   
 $" = 0.07719928$   
 $y_{comp} = 8.1950430E-006$   
with  $f_c' (12.3, (ACI 440)) = 20.42407$   
 $f_c = 20.00$   
 $f_l = 0.62098351$   
 $b = b_{max} = 600.00$   
 $h = h_{max} = 600.00$   
 $A_g = 237500.00$   
 $g = pt + pc + pv = 0.02959978$   
 $rc = 40.00$   
 $A_e / A_c = 0.21783041$   
Effective FRP thickness,  $t_f = NL * t * \text{Cos}(b_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 21019.039$   
 $y = 0.38317351$   
 $A = 0.02940413$   
 $B = 0.01898202$   
with  $E_s = 200000.00$

Calculation of ratio  $l_b / l_d$

Lap Length:  $l_d / l_d, \text{min} = 0.3538123$   
 $l_b = 300.00$   
 $l_d = 847.9072$

Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

db = 18.00

Mean strength value of all re-bars:  $f_y = 444.44$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.61799

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

s = 150.00

n = 16.00

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 10

column C1, Floor 1

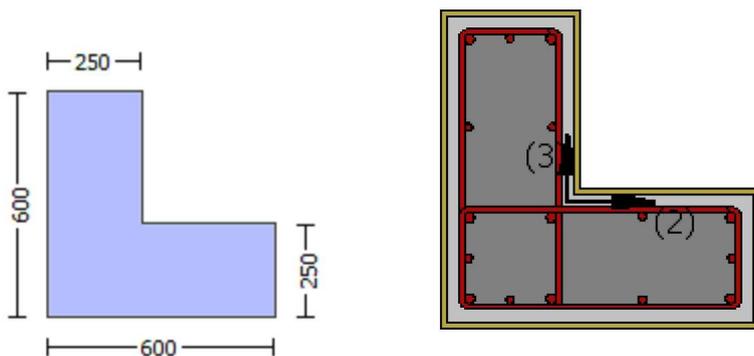
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( u )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdcs

Constant Properties

Knowledge Factor, = 0.77

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

Consequently:

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

```

Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$ 
Concrete Elasticity,  $E_c = 21019.039$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$ 
#####
Max Height,  $H_{max} = 600.00$ 
Min Height,  $H_{min} = 250.00$ 
Max Width,  $W_{max} = 600.00$ 
Min Width,  $W_{min} = 250.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.0981
Element Length,  $L = 3000.00$ 
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length  $l_o = 300.00$ 
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $N_{oDir} = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $N_L = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
At local axis: 3
EDGE -A-
Shear Force,  $V_a = 0.00016213$ 
EDGE -B-
Shear Force,  $V_b = -0.00016213$ 
BOTH EDGES
Axial Force,  $F = -8883.864$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $A_{sl,t} = 0.00$ 
-Compression:  $A_{sl,c} = 4121.77$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $A_{sl,ten} = 1746.726$ 
-Compression:  $A_{sl,com} = 829.3805$ 
-Middle:  $A_{sl,mid} = 1545.664$ 
-----
-----

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.62612363$ 
Member Controlled by Flexure ( $V_e/V_r < 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$ 
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.9843E+008$ 
 $M_{u1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $M_{u1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.9843E+008$ 
 $M_{u2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the static loading combination
 $M_{u2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment

```

direction which is defined for the the static loading combination

Calculation of  $\mu_{1+}$

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

$$u = 1.1848408E-005$$

$$\mu = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max}$  = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min}$  = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length

equal to half the clear spacing between hoops.

$A_{noConf}$  = 105733.333 is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

Lstir (Length of stirrups along Y) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875  
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00  
fywe = 555.55  
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102  
c = confinement factor = 1.0981

y1 = 0.00124738  
sh1 = 0.00431097  
ft1 = 359.2441  
fy1 = 299.3701  
su1 = 0.00446911

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

lo/lou,min = lb/d = 0.28304984

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

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

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

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701  
with Es1 = Es = 200000.00

y2 = 0.00124738  
sh2 = 0.00431097  
ft2 = 359.2441  
fy2 = 299.3701  
su2 = 0.00446911

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

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

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

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701  
with Es2 = Es = 200000.00

yv = 0.00124738  
shv = 0.00431097  
ftv = 359.2441  
fyv = 299.3701  
suv = 0.00446911

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

lo/lou,min = lb/d = 0.28304984

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

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

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701  
with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.18776209  
2 = Asl,com/(b\*d)\*(fs2/fc) = 0.08915322  
v = Asl,mid/(b\*d)\*(fsv/fc) = 0.16614919

and confined core properties:

$b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$   
 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  
 --->  
 $su (4.8) = 0.32281672$   
 $Mu = MRc (4.15) = 3.9843E+008$   
 $u = su (4.1) = 1.1848408E-005$

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

Lap Length:  $l_b/l_d = 0.28304984$   
 $l_b = 300.00$   
 $l_d = 1059.884$   
 Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 18.00$   
 Mean strength value of all re-bars:  $f_y = 555.55$   
 $f_c' = 20.00$ , but  $f_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.61799$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$   
 where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = 150.00$   
 $n = 16.00$

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

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 9.6917274E-006$   
 $Mu = 2.1970E+008$

-----  
 with full section properties:

$b = 600.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00132912$   
 $N = 8883.864$   
 $f_c = 20.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.0144353$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.0144353$   
 $ve ((5.4c), TBDY) = ase * sh, \min * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$   
 where  $f = af * pf * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)  
 -----  
 $f_x = 0.06888919$   
 Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

af = 0.24098246  
with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$   
bmax = 600.00  
hmax = 600.00  
From EC8 A.4.4.3(6), pf =  $2t_f/b_w = 0.008128$   
bw = 250.00  
effective stress from (A.35), ff,e = 703.4155

fy = 0.06888919  
Expression ((15B.6), TBDY) is modified as af =  $1 - (\text{Unconfined area})/(\text{total area})$   
af = 0.24098246  
with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$   
bmax = 600.00  
hmax = 600.00  
From EC8 A.4.4.3(6), pf =  $2t_f/b_w = 0.008128$   
bw = 250.00  
effective stress from (A.35), ff,e = 703.4155

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 =  $Max(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.21805635$   
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,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.  
Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.  
AnoConf = 105733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
psh,min =  $Min(psh,x, psh,y) = 0.00321875$   
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$   
Lstir (Length of stirrups along Y) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$   
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00  
fywe = 555.55  
fce = 20.00  
From ((5.A5), TBDY), TBDY: cc = 0.00298102  
c = confinement factor = 1.0981  
y1 = 0.00124738  
sh1 = 0.00431097  
ft1 = 359.2441  
fy1 = 299.3701  
su1 = 0.00446911  
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
lo/lou,min =  $l_b/l_d = 0.28304984$   
su1 =  $0.4*es_{u1\_nominal} ((5.5), TBDY) = 0.032$   
From table 5A.1, TBDY:  $es_{u1\_nominal} = 0.08$ ,  
For calculation of  $es_{u1\_nominal}$  and y1, sh1, ft1, fy1, it is considered characteristic value  $fs_{y1} = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

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

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

Shear\_factor = 1.00

$lo/lo_{min} = lb/lb_{min} = 0.28304984$

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

From table 5A.1, TBDY:  $esu_{2\_nominal} = 0.08$ ,

For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_2 = fs = 299.3701$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$su_v = 0.00446911$

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

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

Shear\_factor = 1.00

$lo/lo_{min} = lb/ld = 0.28304984$

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

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

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

For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered characteristic value  $fsyv = fs_v/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_v = fs = 299.3701$

with  $Es_v = Es = 200000.00$

$1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.03714718$

$2 = Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.0782342$

$v = Asl_{mid}/(b \cdot d) \cdot (fs_v/fc) = 0.06922883$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, \text{TBDY}) = 21.96205$

$cc (5A.5, \text{TBDY}) = 0.00298102$

$c = \text{confinement factor} = 1.0981$

$1 = Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.04362424$

$2 = Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.09187529$

$v = Asl_{mid}/(b \cdot d) \cdot (fs_v/fc) = 0.08129972$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.17212448$

$Mu = MRc (4.14) = 2.1970E+008$

$u = su (4.1) = 9.6917274E-006$

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

-----  
Lap Length:  $lb/ld = 0.28304984$

$lb = 300.00$

$ld = 1059.884$

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

= 1

$db = 18.00$

Mean strength value of all re-bars:  $f_y = 555.55$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 150.00$

$n = 16.00$

-----  
-----  
-----  
Calculation of  $\mu_{2+}$   
-----

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

$\mu = 1.1848408E-005$

$M_u = 3.9843E+008$

-----  
with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

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

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_c) = 0.0144353$

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

From (5.4b), TBDY:  $\mu_c = 0.0144353$

where ((5.4c), TBDY) =  $\alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where  $f = \alpha^2 * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06888919$

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

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

-----  
 $f_y = 0.06888919$

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

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

-----  
 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$

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,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 105733.333 is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00321875

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

psh,x ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.00124738

sh1 = 0.00431097

ft1 = 359.2441

fy1 = 299.3701

su1 = 0.00446911

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

lo/lou,min = lb/lb = 0.28304984

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, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

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

lo/lou,min = lb/lb,min = 0.28304984

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, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

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

lo/lou,min = lb/lb = 0.28304984

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $e_{sv\_nominal} = 0.08$ ,  
considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $e_{sv\_nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
with  $f_{sv} = f_s = 299.3701$   
with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.18776209$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08915322$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.16614919$

and confined core properties:

$b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.26111925$   
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12398468$   
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.23106236$

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

---->  
 $su (4.8) = 0.32281672$   
 $Mu = MRc (4.15) = 3.9843E+008$   
 $u = su (4.1) = 1.1848408E-005$

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

-----  
Lap Length:  $l_b/l_d = 0.28304984$

$l_b = 300.00$   
 $l_d = 1059.884$

Calculation of  $l_b, \text{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

$db = 18.00$   
Mean strength value of all re-bars:  $f_y = 555.55$   
 $f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.61799$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 157.0796$   
where  $A_{tr\_x}, A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = 150.00$   
 $n = 16.00$

-----  
Calculation of  $Mu_2$ -

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

$u = 9.6917274E-006$   
 $Mu = 2.1970E+008$

-----  
with full section properties:

$b = 600.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00132912$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$\text{we ((5.4c), TBDY)} = a_s e^* \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,\min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1460.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$ft1 = 359.2441$   
 $fy1 = 299.3701$   
 $su1 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/l_d = 0.28304984$   
 $su1 = 0.4*esu1\_nominal ((5.5), TBDY) = 0.032$   
 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  $Min(1,1.25*(lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs1 = fs = 299.3701$   
 with  $Es1 = Es = 200000.00$   
 $y2 = 0.00124738$   
 $sh2 = 0.00431097$   
 $ft2 = 359.2441$   
 $fy2 = 299.3701$   
 $su2 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/l_b,min = 0.28304984$   
 $su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$   
 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  $Min(1,1.25*(lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs2 = fs = 299.3701$   
 with  $Es2 = Es = 200000.00$   
 $yv = 0.00124738$   
 $shv = 0.00431097$   
 $ftv = 359.2441$   
 $fyv = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/l_d = 0.28304984$   
 $suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv,ftv,fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1,ft1,fy1$ , are also multiplied by  $Min(1,1.25*(lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 299.3701$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883$   
 and confined core properties:  
 $b = 540.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.17212448$   
 $Mu = MRc (4.14) = 2.1970E+008$

$$u = s_u(4.1) = 9.6917274E-006$$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.28304984$

$$l_b = 300.00$$

$$l_d = 1059.884$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 150.00$$

$$n = 16.00$$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1,  $V_{r1} = 424229.688$

$$V_{r1} = V_{Co1} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Co10}$$

$$V_{Co10} = 424229.688$$

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

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

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 47.24078$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 316483.206$$

where:

$V_{s1} = 223399.91$  is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$$s/d = 0.3125$$

$V_{s2} = 93083.296$  is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$$s/d = 0.75$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$$

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

$w_f/s_f = 1$  (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  $\alpha$  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:  $\theta_1 = \theta_{b1} + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 557.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 356502.845$   
 $b_w = 250.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 424229.688$   
 $V_{r2} = V_{CoI0}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{CoI0}$   
 $V_{CoI0} = 424229.688$   
 $k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s$ ' 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)  
 $f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $M_u = 47.24081$   
 $V_u = 0.00016213$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 8883.864$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$   
where:

$V_{s1} = 223399.91$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$

$V_{s2} = 93083.296$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$

$V_f$  ((11-3)-(11.4), ACI 440) = 293495.545  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).

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

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

orientation 1:  $\theta_1 = \theta_{b1} + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:  
total thickness per orientation,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 557.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 356502.845$   
 $b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rclcs

Constant Properties

-----  
Knowledge Factor,  $\phi = 0.77$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
#####  
Note: Especially for the calculation of moment strengths,  
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
#####  
Max Height,  $H_{max} = 600.00$   
Min Height,  $H_{min} = 250.00$   
Max Width,  $W_{max} = 600.00$   
Min Width,  $W_{min} = 250.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.0981  
Element Length,  $L = 3000.00$   
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i = 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$   
-----

Stepwise Properties

-----  
At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = 0.00016213$   
EDGE -B-  
Shear Force,  $V_b = -0.00016213$   
BOTH EDGES  
Axial Force,  $F = -8883.864$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 4121.77$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{l,ten} = 1746.726$   
-Compression:  $As_{l,com} = 829.3805$   
-Middle:  $As_{l,mid} = 1545.664$   
-----  
-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.62612363$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with  
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 3.9843E+008$   
 $M_{u1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $M_{u1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 3.9843E+008$   
 $M_{u2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $M_{u2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

-----  
Calculation of  $M_{u1+}$   
-----

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

$\phi_u = 1.1848408E-005$

$M_u = 3.9843E+008$   
-----

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

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

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.0144353$

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

From (5.4b), TBDY:  $\phi_u = 0.0144353$

$\omega_e$  ((5.4c), TBDY) =  $\alpha_1 * \text{sh,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

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

-----  
 $f_x = 0.06888919$

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

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 57233.333$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

From EC8 A 4.4.3(6),  $\rho_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$   
-----

$f_y = 0.06888919$

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

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 0.00$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

From EC8 A 4.4.3(6),  $\rho_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$   
-----

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.  
 $A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

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

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c = \text{confinement factor} = 1.0981$

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

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

$l_o/l_{o,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

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

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_2 = fs = 299.3701$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$su_v = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.28304984$$

$$s_{uv} = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{suv\_nominal} = 0.08$ ,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv\_nominal}$  and  $\gamma_v$ ,  $sh_v, ft_v, fy_v$ , it is considered characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$\gamma_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 299.3701$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.18776209$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.08915322$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.16614919$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 21.96205$$

$$c_c (5A.5, TBDY) = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.26111925$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.12398468$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.23106236$$

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

---->

$$s_u (4.8) = 0.32281672$$

$$M_u = M_{Rc} (4.15) = 3.9843E+008$$

$$u = s_u (4.1) = 1.1848408E-005$$

-----  
Calculation of ratio  $l_b/l_d$   
-----

Lap Length:  $l_b/l_d = 0.28304984$

$$l_b = 300.00$$

$$l_d = 1059.884$$

Calculation of  $l_b, min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$f'_c = 20.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 157.0796$$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = 150.00$$

$$n = 16.00$$

-----  
Calculation of  $M_u1$ -  
-----

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 9.6917274E-006$$

$$M_u = 2.1970E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along X}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

y1 = 0.00124738  
sh1 = 0.00431097  
ft1 = 359.2441  
fy1 = 299.3701  
su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.28304984

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738  
sh2 = 0.00431097  
ft2 = 359.2441  
fy2 = 299.3701  
su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738  
shv = 0.00431097  
ftv = 359.2441  
fyv = 299.3701  
suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.28304984

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.03714718

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0782342

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06922883

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04362424

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09187529

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.08129972

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

v < vs,y2 - LHS eq.(4.5) is satisfied

---->

su (4.9) = 0.17212448  
Mu = MRc (4.14) = 2.1970E+008  
u = su (4.1) = 9.6917274E-006

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Lap Length: lb/l<sub>d</sub> = 0.28304984

lb = 300.00

l<sub>d</sub> = 1059.884

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: f<sub>y</sub> = 555.55

f<sub>c</sub>' = 20.00, but f<sub>c</sub>'<sup>0.5</sup> ≤ 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K<sub>tr</sub> = 2.61799

A<sub>tr</sub> = Min(A<sub>tr\_x</sub>, A<sub>tr\_y</sub>) = 157.0796

where A<sub>tr\_x</sub>, A<sub>tr\_y</sub> are the sum of the area of all stirrup legs along X and Y loxal axis

s = 150.00

n = 16.00

-----  
-----  
-----  
Calculation of Mu<sub>2+</sub>

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.1848408E-005

Mu = 3.9843E+008

-----  
with full section properties:

b = 250.00

d = 557.00

d' = 43.00

v = 0.0031899

N = 8883.864

f<sub>c</sub>' = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.0144353

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.0144353

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.07473805

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.06888919

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.24098246

with Unconfined area = ((bmax-2R)<sup>2</sup> + (hmax-2R)<sup>2</sup>)/3 = 57233.333

bmax = 600.00

hmax = 600.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128

bw = 250.00

effective stress from (A.35), ff,e = 703.4155

-----  
fy = 0.06888919

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.24098246

with Unconfined area = ((bmax-2R)<sup>2</sup> + (hmax-2R)<sup>2</sup>)/3 = 0.00

bmax = 600.00

hmax = 600.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128

bw = 250.00

effective stress from (A.35),  $f_{f,e} = 703.4155$

$R = 40.00$

Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c$  = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$

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.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs2 = fs = 299.3701$

with  $Es2 = Es = 200000.00$

$yv = 0.00124738$

$shv = 0.00431097$

$ftv = 359.2441$

$fyv = 299.3701$

$suv = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lou, \min = lb/ld = 0.28304984$

$suv = 0.4 \cdot esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY:  $esuv_{\text{nominal}} = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv_{\text{nominal}}$  and  $yv, shv, ftv, fyv$ , it is considered

characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fsv = fs = 299.3701$

with  $Es = Es = 200000.00$

1 =  $Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.18776209$

2 =  $Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.08915322$

v =  $Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.16614919$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$fcc (5A.2, \text{TBDY}) = 21.96205$

$cc (5A.5, \text{TBDY}) = 0.00298102$

c = confinement factor = 1.0981

1 =  $Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.26111925$

2 =  $Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.12398468$

v =  $Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.23106236$

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

--->

$su (4.8) = 0.32281672$

$Mu = MRc (4.15) = 3.9843E+008$

$u = su (4.1) = 1.1848408E-005$

-----  
Calculation of ratio  $lb/ld$

-----  
Lap Length:  $lb/ld = 0.28304984$

$lb = 300.00$

$ld = 1059.884$

Calculation of  $lb, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars:  $fy = 555.55$

$fc' = 20.00$ , but  $fc^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

$cb = 25.00$

$Ktr = 2.61799$

$Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$

where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis

s = 150.00

n = 16.00

## Calculation of Mu2-

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.6917274E-006$$

$$Mu = 2.1970E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, c_o) = 0.0144353$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.0144353$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e^* s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,\min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00321875$$

$$Lstir (\text{Length of stirrups along } X) = 1460.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y1 = 0.00124738$$

$$sh1 = 0.00431097$$

$$ft1 = 359.2441$$

$$fy1 = 299.3701$$

$$su1 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lou,min = lb/ld = 0.28304984$$

$$su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$$

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, ASCE41-17.

$$\text{with } fs1 = fs = 299.3701$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00124738$$

$$sh2 = 0.00431097$$

$$ft2 = 359.2441$$

$$fy2 = 299.3701$$

$$su2 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.28304984$$

$$su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$$

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, ASCE41-17.

$$\text{with } fs2 = fs = 299.3701$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00124738$$

$$shv = 0.00431097$$

$$ftv = 359.2441$$

$$fyv = 299.3701$$

$$suv = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lou,min = lb/ld = 0.28304984$$

$$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv, ftv, fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 299.3701$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.03714718$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.0782342$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.06922883$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$f_{cc}$  (5A.2, TBDY) = 21.96205  
 $cc$  (5A.5, TBDY) = 0.00298102  
 $c$  = confinement factor = 1.0981  
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04362424$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09187529$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08129972$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->  
 $\mu_u$  (4.9) = 0.17212448  
 $\mu_u = MR_c$  (4.14) = 2.1970E+008  
 $u = \mu_u$  (4.1) = 9.6917274E-006

-----  
Calculation of ratio  $l_b/l_d$

-----  
Lap Length:  $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

$d_b = 18.00$

Mean strength value of all re-bars:  $f_y = 555.55$

$f'_c = 20.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 424229.688$

$V_{r1} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$

$V_{Col0} = 424229.688$

$k_{nl} = 1$  (zero step-static loading)

-----  
NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_{s+} = f * V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

-----  
= 1 (normal-weight concrete)

$f'_c = 20.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 47.23669$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 93083.296$  is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.75$

$V_{s2} = 223399.91$  is calculated for section flange, with:

$d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$   
 Vs2 is multiplied by Col2 = 1.00  
 $s/d = 0.3125$   
 $V_f((11-3)-(11.4), \text{ACI 440}) = 293495.545$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $\theta$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 557.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 356502.845$   
 $b_w = 250.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 424229.688$   
 $V_{r2} = V_{Col}((10.3), \text{ASCE 41-17}) = k_{nl} * V_{Col0}$   
 $V_{Col0} = 424229.688$   
 $k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf'  
 where Vf is the contribution of FRPs (11.3), ACI 440).

$\rho = 1$  (normal-weight concrete)  
 $f'_c = 20.00$ , but  $f'_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 47.23667$   
 $\nu_u = 0.00016213$   
 $d = 0.8 * h = 480.00$   
 $N_u = 8883.864$   
 $A_g = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$   
 where:  
 $V_{s1} = 93083.296$  is calculated for section web, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by Col1 = 1.00  
 $s/d = 0.75$   
 $V_{s2} = 223399.91$  is calculated for section flange, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by Col2 = 1.00  
 $s/d = 0.3125$   
 $V_f((11-3)-(11.4), \text{ACI 440}) = 293495.545$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $\theta$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / \text{NoDir} = 1.016$

dfv = d (figure 11.2, ACI 440) = 557.00  
ffe ((11-5), ACI 440) = 259.312  
Ef = 64828.00  
fe = 0.004, from (11.6a), ACI 440  
with fu = 0.01  
From (11-11), ACI 440: Vs + Vf <= 356502.845  
bw = 250.00

-----  
-----  
End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 2

-----  
-----  
Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1  
At local axis: 2  
Integration Section: (a)  
Section Type: rclcs

#### Constant Properties

-----  
Knowledge Factor, = 0.77  
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.  
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
Consequently:  
Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00  
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44  
Concrete Elasticity, Ec = 21019.039  
Steel Elasticity, Es = 200000.00  
Max Height, Hmax = 600.00  
Min Height, Hmin = 250.00  
Max Width, Wmax = 600.00  
Min Width, Wmin = 250.00  
Cover Thickness, c = 25.00  
Element Length, L = 3000.00  
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length lb = 300.00  
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness, t = 1.016  
Tensile Strength, ffu = 1055.00  
Tensile Modulus, Ef = 64828.00  
Elongation, efu = 0.01  
Number of directions, NoDir = 1  
Fiber orientations, bi: 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

#### Stepwise Properties

-----  
Bending Moment, M = -266395.829  
Shear Force, V2 = -3536.316  
Shear Force, V3 = 123.1168  
Axial Force, F = -9530.256  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 4121.77  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 1746.726  
-Compression: Asl,com = 829.3805

-Middle:  $Asl_{mid} = 1545.664$

Mean Diameter of Tension Reinforcement,  $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{R} = u = 0.03622669$   
 $u = y + p = 0.04704765$

- Calculation of  $y$  -

$y = (My * Ls / 3) / Eleff = 0.00504765$  ((4.29), Biskinis Phd)  
 $My = 2.9338E+008$   
 $Ls = M/V$  (with  $Ls > 0.1 * L$  and  $Ls < 2 * L$ ) = 2163.765  
From table 10.5, ASCE 41\_17:  $Eleff = factor * Ec * Ig = 4.1921E+013$   
factor = 0.30  
 $Ag = 237500.00$   
 $fc' = 20.00$   
 $N = 9530.256$   
 $Ec * Ig = 1.3974E+014$

Calculation of Yielding Moment  $My$

Calculation of  $y$  and  $My$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.0516275E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (lb/d)^{2/3}) = 277.9106$   
 $d = 557.00$   
 $y = 0.38426988$   
 $A = 0.02984605$   
 $B = 0.01922829$   
with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9530.256$   
 $b = 250.00$   
 $" = 0.07719928$   
 $y_{comp} = 8.1950430E-006$   
with  $fc' (12.3, (ACI 440)) = 20.42407$   
 $fc = 20.00$   
 $fl = 0.62098351$   
 $b = b_{max} = 600.00$   
 $h = h_{max} = 600.00$   
 $Ag = 237500.00$   
 $g = pt + pc + pv = 0.02959978$   
 $rc = 40.00$   
 $Ae/Ac = 0.21783041$   
Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$   
effective strain from (12.5) and (12.12),  $e_{fe} = 0.004$   
 $fu = 0.01$   
 $Ef = 64828.00$   
 $Ec = 21019.039$   
 $y = 0.38317351$   
 $A = 0.02940413$   
 $B = 0.01898202$   
with  $Es = 200000.00$

Calculation of ratio  $lb/d$

Lap Length:  $ld/ld_{min} = 0.3538123$   
 $lb = 300.00$

$$l_d = 847.9072$$

Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars:  $f_y = 444.44$

$$f'_c = 20.00, \text{ but } f'_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = 150.00$$

$$n = 16.00$$

-----  
- Calculation of  $\rho$  -  
-----

From table 10-8:  $\rho = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/l_d \geq 1$

$$\text{shear control ratio } V_y E / V_{col} O E = 0.62612363$$

$$d = 557.00$$

$$s = 0.00$$

$$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1460.00$ , is the total Length of all stirrups parallel to loading (shear) direction

The term  $2 * t_f / b_w * (f_{fe} / f_s)$  is implemented to account for FRP contribution

where  $f = 2 * t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength

All these variables have already been given in Shear control ratio calculation.

$$N_{UD} = 9530.256$$

$$A_g = 237500.00$$

$$f'_c E = 20.00$$

$$f_{yt} E = f_{yl} E = 0.00$$

$$\rho_l = \text{Area\_Tot\_Long\_Rein} / (b * d) = 0.02959978$$

$$b = 250.00$$

$$d = 557.00$$

$$f'_c E = 20.00$$

-----  
End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)  
-----

## Calculation No. 11

column C1, Floor 1

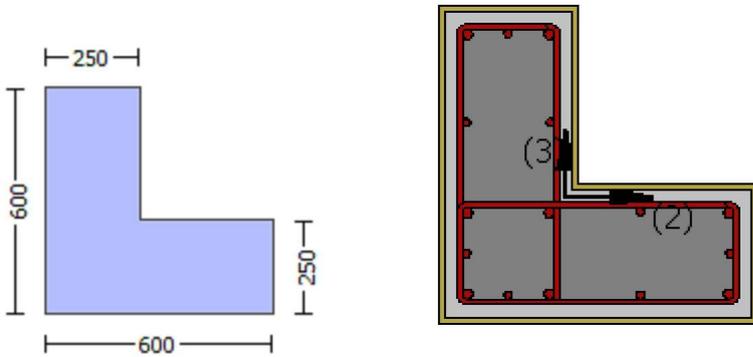
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$

Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$

Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $\epsilon_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $b_i = 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties  
-----

EDGE -A-  
Bending Moment,  $M_a = -266395.829$   
Shear Force,  $V_a = 123.1168$   
EDGE -B-  
Bending Moment,  $M_b = -101614.073$   
Shear Force,  $V_b = -123.1168$   
BOTH EDGES  
Axial Force,  $F = -9530.256$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_{lt} = 0.00$   
-Compression:  $As_{lc} = 4121.77$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{l,ten} = 1746.726$   
-Compression:  $As_{l,com} = 829.3805$   
-Middle:  $As_{l,mid} = 1545.664$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.71429$

-----  
Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 292291.023$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \phi V_{CoI0} = 379598.731$   
 $V_{CoI} = 379598.731$   
 $k_n = 1.00$   
 $displacement\_ductility\_demand = 0.00780743$

-----  
NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_{s+} = \phi V_f$ '  
where  $V_f$  is the contribution of FRPs ((11.3), ACI 440).

-----  
 $\phi = 1$  (normal-weight concrete)  
 $f'_c = 16.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $M_u = 266395.829$   
 $V_u = 123.1168$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 9530.256$   
 $A_g = 150000.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 284837.734$   
where:  
 $V_{s1} = 201061.93$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 83775.804$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f$  ((11-3)-(11.4), ACI 440) =  $293495.545$   
 $\phi = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
In (11.3)  $\sin^2 \theta + \cos^2 \theta$  is replaced with  $(\cot^2 \theta + \csc^2 \theta) \sin^2 \theta$  which is more a generalised expression,

where  $\theta$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta)$ , 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) = 557.00

$f_{fe}$  ((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:  $V_s + V_f \leq 318865.838$

$b_w = 250.00$

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  $\theta = 3.9409129E-005$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00504765$  ((4.29), Biskinis Phd)

$M_y = 2.9338E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 2163.765

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9530.256$

$E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 4.0516275E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 277.9106$

$d = 557.00$

$y = 0.38426988$

$A = 0.02984605$

$B = 0.01922829$

with  $p_t = 0.01254381$

$p_c = 0.00595605$

$p_v = 0.01109992$

$N = 9530.256$

$b = 250.00$

$\alpha = 0.07719928$

$y_{comp} = 8.1950430E-006$

with  $f_c^*$  (12.3, (ACI 440)) = 20.42407

$f_c = 20.00$

$f_l = 0.62098351$

$b = b_{max} = 600.00$

$h = h_{max} = 600.00$

$A_g = 237500.00$

$g = p_t + p_c + p_v = 0.02959978$

$r_c = 40.00$

$A_e / A_c = 0.21783041$

Effective FRP thickness,  $t_f = NL \cdot t \cdot \text{Cos}(b1) = 1.016$

effective strain from (12.5) and (12.12),  $e_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.38317351$

A = 0.02940413  
B = 0.01898202  
with Es = 200000.00

Calculation of ratio  $l_b/d$

Lap Length:  $l_d/d, \min = 0.3538123$

$l_b = 300.00$

$l_d = 847.9072$

Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars:  $f_y = 444.44$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 12

column C1, Floor 1

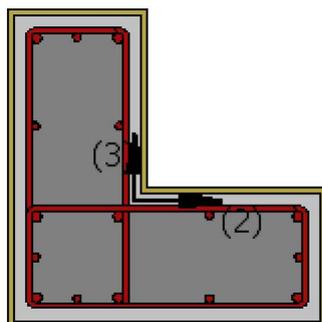
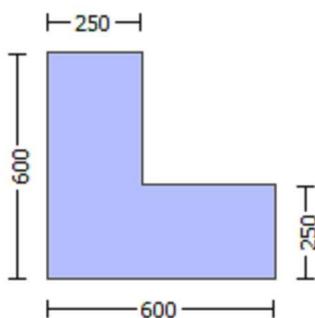
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta_u$ )

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At Shear local axis: 3  
(Bending local axis: 2)  
Section Type: rdcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$   
#####

Note: Especially for the calculation of moment strengths,  
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$   
#####

Max Height,  $H_{max} = 600.00$   
Min Height,  $H_{min} = 250.00$   
Max Width,  $W_{max} = 600.00$   
Min Width,  $W_{min} = 250.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.0981  
Element Length,  $L = 3000.00$   
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
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,  $V_a = 0.00016213$   
EDGE -B-  
Shear Force,  $V_b = -0.00016213$   
BOTH EDGES  
Axial Force,  $F = -8883.864$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl} = 0.00$   
-Compression:  $A_{slc} = 4121.77$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1746.726$   
-Compression:  $A_{sl,com} = 829.3805$   
-Middle:  $A_{sl,mid} = 1545.664$

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.62612363$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with  
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 3.9843E+008$   
 $M_{u1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $M_{u1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 3.9843E+008$   
 $M_{u2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $M_{u2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

-----  
Calculation of  $M_{u1+}$   
-----

-----  
Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.1848408E-005$

$M_u = 3.9843E+008$   
-----

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

$\alpha_1$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.0144353$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.0144353$

$\omega_e$  ((5.4c), TBDY) =  $\alpha_1 * \text{sh,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where  $f = \alpha_f * \rho_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 57233.333$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

From EC8 A 4.4.3(6),  $\rho_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$   
-----

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 0.00$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

From EC8 A 4.4.3(6),  $\rho_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$   
-----

$R = 40.00$

Effective FRP thickness,  $t_f = N_L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.  
 $A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

-----  
 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c =$  confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$

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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_2 = fs = 299.3701$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$su_v = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.28304984$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{suv,nominal} = 0.08$ ,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv,nominal}$  and  $\gamma_v$ ,  $sh_v, ft_v, fy_v$ , it is considered characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$\gamma_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 299.3701$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.18776209$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.08915322$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.16614919$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 21.96205$$

$$c_c (5A.5, TBDY) = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.26111925$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.12398468$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.23106236$$

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

---->

$$s_u (4.8) = 0.32281672$$

$$M_u = M_{Rc} (4.15) = 3.9843E+008$$

$$u = s_u (4.1) = 1.1848408E-005$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Lap Length:  $l_b/l_d = 0.28304984$

$$l_b = 300.00$$

$$l_d = 1059.884$$

Calculation of  $l_b,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$$f'_c = 20.00, \text{ but } f'_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = 150.00$$

$$n = 16.00$$

-----  
Calculation of  $M_u1-$

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 9.6917274E-006$$

$$M_u = 2.1970E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$\text{we ((5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY) } = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y) } = 1460.00$$

$$A_{stir} \text{ (stirrups area) } = 78.53982$$

$$A_{sec} \text{ (section area) } = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY) } = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X) } = 1460.00$$

$$A_{stir} \text{ (stirrups area) } = 78.53982$$

$$A_{sec} \text{ (section area) } = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

y1 = 0.00124738  
sh1 = 0.00431097  
ft1 = 359.2441  
fy1 = 299.3701  
su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.28304984

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738  
sh2 = 0.00431097  
ft2 = 359.2441  
fy2 = 299.3701  
su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738  
shv = 0.00431097  
ftv = 359.2441  
fyv = 299.3701  
suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.28304984

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.03714718

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0782342

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06922883

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.04362424

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09187529

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.08129972

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

v < vs,y2 - LHS eq.(4.5) is satisfied

---->

su (4.9) = 0.17212448  
Mu = MRc (4.14) = 2.1970E+008  
u = su (4.1) = 9.6917274E-006

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Lap Length: lb/l<sub>d</sub> = 0.28304984

lb = 300.00

l<sub>d</sub> = 1059.884

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: f<sub>y</sub> = 555.55

f<sub>c</sub>' = 20.00, but f<sub>c</sub>'<sup>0.5</sup> ≤ 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K<sub>tr</sub> = 2.61799

A<sub>tr</sub> = Min(A<sub>tr\_x</sub>, A<sub>tr\_y</sub>) = 157.0796

where A<sub>tr\_x</sub>, A<sub>tr\_y</sub> are the sum of the area of all stirrup legs along X and Y loxal axis

s = 150.00

n = 16.00

-----  
-----  
-----  
Calculation of Mu<sub>2+</sub>

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.1848408E-005

Mu = 3.9843E+008

-----  
with full section properties:

b = 250.00

d = 557.00

d' = 43.00

v = 0.0031899

N = 8883.864

f<sub>c</sub> = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.0144353

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.0144353

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.07473805

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.06888919

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.24098246

with Unconfined area = ((bmax-2R)<sup>2</sup>+ (hmax-2R)<sup>2</sup>)/3 = 57233.333

bmax = 600.00

hmax = 600.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128

bw = 250.00

effective stress from (A.35), ff,e = 703.4155

-----  
fy = 0.06888919

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.24098246

with Unconfined area = ((bmax-2R)<sup>2</sup>+ (hmax-2R)<sup>2</sup>)/3 = 0.00

bmax = 600.00

hmax = 600.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128

bw = 250.00

effective stress from (A.35),  $f_{f,e} = 703.4155$

$R = 40.00$

Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c$  = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 \cdot esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 \cdot esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$

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.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs2 = fs = 299.3701$

with  $Es2 = Es = 200000.00$

$yv = 0.00124738$

$shv = 0.00431097$

$ftv = 359.2441$

$fyv = 299.3701$

$suv = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$lo/lou, \min = lb/ld = 0.28304984$

$suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$

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, ASCE41-17.

with  $fsv = fs = 299.3701$

with  $Es = Es = 200000.00$

1 =  $Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.18776209$

2 =  $Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.08915322$

v =  $Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.16614919$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 21.96205$

$cc (5A.5, TBDY) = 0.00298102$

c = confinement factor = 1.0981

1 =  $Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.26111925$

2 =  $Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.12398468$

v =  $Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.23106236$

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

---

$su (4.8) = 0.32281672$

$Mu = MRc (4.15) = 3.9843E+008$

$u = su (4.1) = 1.1848408E-005$

-----  
Calculation of ratio  $lb/ld$

-----  
Lap Length:  $lb/ld = 0.28304984$

$lb = 300.00$

$ld = 1059.884$

Calculation of  $lb, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars:  $fy = 555.55$

$fc' = 20.00$ , but  $fc^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

$cb = 25.00$

$Ktr = 2.61799$

$Atr = \text{Min}(Atr\_x, Atr\_y) = 157.0796$

where  $Atr\_x, Atr\_y$  are the sum of the area of all stirrup legs along X and Y loxal axis

s = 150.00

n = 16.00

## Calculation of Mu2-

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.6917274E-006$$

$$Mu = 2.1970E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear\_factor} * \text{Max}(\mu, c_o) = 0.0144353$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.0144353$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e^* \text{ sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{ Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,\min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

psh,y ((5.4d), TBDY) =  $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.00124738

sh1 = 0.00431097

ft1 = 359.2441

fy1 = 299.3701

su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/l\_d = 0.28304984

su1 =  $0.4 \cdot esu1_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/l\_b,min = 0.28304984

su2 =  $0.4 \cdot esu2_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/l\_d = 0.28304984

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  $\text{Min}(1, 1.25 \cdot (lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 =  $Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.03714718$

2 =  $Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.0782342$

v =  $Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.06922883$

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

$f_{cc}$  (5A.2, TBDY) = 21.96205  
 $c_c$  (5A.5, TBDY) = 0.00298102  
 $c$  = confinement factor = 1.0981  
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04362424$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09187529$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08129972$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $\mu_u$  (4.9) = 0.17212448  
 $M_u = M_{Rc}$  (4.14) = 2.1970E+008  
 $u = \mu_u$  (4.1) = 9.6917274E-006

-----  
 Calculation of ratio  $l_b/l_d$   
 -----

Lap Length:  $l_b/l_d = 0.28304984$   
 $l_b = 300.00$   
 $l_d = 1059.884$   
 Calculation of  $l_b$ ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $d_b = 18.00$   
 Mean strength value of all re-bars:  $f_y = 555.55$   
 $f'_c = 20.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $c_b = 25.00$   
 $K_{tr} = 2.61799$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$   
 where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = 150.00$   
 $n = 16.00$

-----  
 Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$   
 -----

Calculation of Shear Strength at edge 1,  $V_{r1} = 424229.688$   
 $V_{r1} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$   
 $V_{Col0} = 424229.688$   
 $k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_{s+} + V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$= 1$  (normal-weight concrete)  
 $f'_c = 20.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 47.24078$   
 $V_u = 0.00016213$   
 $d = 0.8*h = 480.00$   
 $N_u = 8883.864$   
 $A_g = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$   
 where:  
 $V_{s1} = 223399.91$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 93083.296$  is calculated for section flange, with:

$d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 293495.545  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $\theta$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 557.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 356502.845$   
 $bw = 250.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 424229.688$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_n l \cdot V_{Col0}$   
 $V_{Col0} = 424229.688$   
 $k_n l = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s$ ' 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)  
 $f'_c = 20.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/d = 4.00$   
 $\mu_u = 47.24081$   
 $\nu_u = 0.00016213$   
 $d = 0.8 \cdot h = 480.00$   
 $N_u = 8883.864$   
 $A_g = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$   
 where:  
 $V_{s1} = 223399.91$  is calculated for section web, with:  
 $d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $V_{s2} = 93083.296$  is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 293495.545  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $\theta$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $tf_1 = NL \cdot t / \text{NoDir} = 1.016$

dfv = d (figure 11.2, ACI 440) = 557.00  
ffe ((11-5), ACI 440) = 259.312  
Ef = 64828.00  
fe = 0.004, from (11.6a), ACI 440  
with fu = 0.01  
From (11-11), ACI 440: Vs + Vf <= 356502.845  
bw = 250.00

-----  
End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 3  
-----

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rclcs

#### Constant Properties

-----  
Knowledge Factor, = 0.77  
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00  
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44  
Concrete Elasticity, Ec = 21019.039  
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  
Existing material: Steel Strength, fs = 1.25\*fsm = 555.55  
#####  
Max Height, Hmax = 600.00  
Min Height, Hmin = 250.00  
Max Width, Wmax = 600.00  
Min Width, Wmin = 250.00  
Cover Thickness, c = 25.00  
Mean Confinement Factor overall section = 1.0981  
Element Length, L = 3000.00  
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length lo = 300.00  
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness, t = 1.016  
Tensile Strength, ffu = 1055.00  
Tensile Modulus, Ef = 64828.00  
Elongation, efu = 0.01  
Number of directions, NoDir = 1  
Fiber orientations, bi: 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00  
-----

#### Stepwise Properties

-----  
At local axis: 2  
EDGE -A-  
Shear Force, Va = 0.00016213  
EDGE -B-  
Shear Force, Vb = -0.00016213  
-----

BOTH EDGES

Axial Force,  $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{,ten} = 1746.726$

-Compression:  $As_{,com} = 829.3805$

-Middle:  $As_{,mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.62612363$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.9843E+008$

$M_{u1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.9843E+008$

$M_{u2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of  $M_{u1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.1848408E-005$

$M_u = 3.9843E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

$\omega (5A.5, \text{TBDY}) = 0.002$

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.0144353$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.0144353$

$\omega_e (5.4c, \text{TBDY}) = a_s e^* \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.24098246$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.24098246$

with Unconfined area =  $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $pf = 2t_f/bw = 0.008128$   
 $bw = 250.00$   
effective stress from (A.35),  $ff_e = 703.4155$

$R = 40.00$   
Effective FRP thickness,  $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$   
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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $psh_{,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along Y) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

$psh_{,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along X) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

$s = 150.00$   
 $f_{ywe} = 555.55$   
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$

$y_1 = 0.00124738$   
 $sh_1 = 0.00431097$   
 $ft_1 = 359.2441$   
 $fy_1 = 299.3701$   
 $su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 \cdot esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fs_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $fy_2 = 299.3701$   
 $su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 \cdot esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,

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, ASCE41-17.

with  $fs_2 = fs = 299.3701$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$s_{uv} = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.28304984$

$s_{uv} = 0.4 \cdot es_{uv\_nominal} ((5,5), TBDY) = 0.032$

From table 5A.1, TBDY:  $es_{uv\_nominal} = 0.08$ ,

considering characteristic value  $fs_{yv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $es_{uv\_nominal}$  and  $y_v$ ,  $sh_v, ft_v, fy_v$ , it is considered characteristic value  $fs_{yv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{sv} = fs = 299.3701$

with  $Es_v = Es = 200000.00$

1 =  $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.18776209$

2 =  $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08915322$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.16614919$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 21.96205$

$cc (5A.5, TBDY) = 0.00298102$

$c = \text{confinement factor} = 1.0981$

1 =  $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.26111925$

2 =  $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12398468$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.23106236$

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

--->

$s_u (4.8) = 0.32281672$

$\mu_u = MR_c (4.15) = 3.9843E+008$

$u = s_u (4.1) = 1.1848408E-005$

-----  
Calculation of ratio  $lb/ld$

-----  
Lap Length:  $lb/ld = 0.28304984$

$lb = 300.00$

$ld = 1059.884$

Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars:  $f_y = 555.55$

$f'_c = 20.00$ , but  $f_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 157.0796$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 150.00$

$n = 16.00$

Calculation of Mu1-

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.6917274E-006$$

$$Mu = 2.1970E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,\min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875  
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00  
fywe = 555.55  
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102  
c = confinement factor = 1.0981

y1 = 0.00124738  
sh1 = 0.00431097  
ft1 = 359.2441  
fy1 = 299.3701  
su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.28304984

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738  
sh2 = 0.00431097  
ft2 = 359.2441  
fy2 = 299.3701  
su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738  
shv = 0.00431097  
ftv = 359.2441  
fyv = 299.3701  
suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.28304984

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.03714718

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0782342

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06922883

and confined core properties:

b = 540.00

$d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04362424$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09187529$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08129972$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.17212448$   
 $Mu = MRc (4.14) = 2.1970E+008$   
 $u = su (4.1) = 9.6917274E-006$

-----  
 Calculation of ratio  $l_b/l_d$

-----  
 Lap Length:  $l_b/l_d = 0.28304984$   
 $l_b = 300.00$   
 $l_d = 1059.884$   
 Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 18.00$   
 Mean strength value of all re-bars:  $f_y = 555.55$   
 $f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.61799$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$   
 where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = 150.00$   
 $n = 16.00$

-----  
 Calculation of  $Mu_{2+}$

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 1.1848408E-005$   
 $Mu = 3.9843E+008$

-----  
 with full section properties:

$b = 250.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00318999$   
 $N = 8883.864$   
 $f_c = 20.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.0144353$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.0144353$   
 $we ((5.4c), TBDY) = ase^* sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$   
 where  $f = af * \rho_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)  
 -----  
 $f_x = 0.06888919$   
 Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
 $af = 0.24098246$   
 with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$   
 $b_{max} = 600.00$

hmax = 600.00  
From EC8 A 4.4.3(6),  $pf = 2tf/bw = 0.008128$   
bw = 250.00  
effective stress from (A.35),  $ff,e = 703.4155$

fy = 0.06888919  
Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
af = 0.24098246  
with Unconfined area =  $((bmax-2R)^2 + (hmax-2R)^2)/3 = 0.00$   
bmax = 600.00  
hmax = 600.00  
From EC8 A 4.4.3(6),  $pf = 2tf/bw = 0.008128$   
bw = 250.00  
effective stress from (A.35),  $ff,e = 703.4155$

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 =  $Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.21805635$

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,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 105733.333 is the unconfined core area which is equal to  $bi^2/6$  as defined at (A.2).

psh,min =  $Min(psh,x, psh,y) = 0.00321875$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) =  $Lstir*Astir/(Asec*s) = 0.00321875$   
Lstir (Length of stirrups along Y) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) =  $Lstir*Astir/(Asec*s) = 0.00321875$   
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00  
fywe = 555.55  
fce = 20.00

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$   
c = confinement factor = 1.0981

y1 = 0.00124738  
sh1 = 0.00431097  
ft1 = 359.2441  
fy1 = 299.3701  
su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min =  $lb/d = 0.28304984$

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, ASCE41-17.

with  $fs1 = fs = 299.3701$

with  $Es1 = Es = 200000.00$

$y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $fy_2 = 299.3701$   
 $su_2 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{min} = lb/lb_{min} = 0.28304984$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs_2 = fs = 299.3701$   
 with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $fy_v = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{min} = lb/ld = 0.28304984$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 299.3701$   
 with  $Esv = Es = 200000.00$

$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.18776209$   
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.08915322$   
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.16614919$

and confined core properties:

$b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.26111925$   
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.12398468$   
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.23106236$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is not satisfied

--->  
 $v < v_{s,c}$  - RHS eq.(4.5) is satisfied

--->  
 $su (4.8) = 0.32281672$   
 $Mu = MRc (4.15) = 3.9843E+008$   
 $u = su (4.1) = 1.1848408E-005$

-----  
 Calculation of ratio  $lb/ld$

-----  
 Lap Length:  $lb/ld = 0.28304984$   
 $lb = 300.00$   
 $ld = 1059.884$   
 Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 18.00$   
 Mean strength value of all re-bars:  $fy = 555.55$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

-----  
Calculation of  $\mu_2$ -  
-----

-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.6917274E-006$

$M_u = 2.1970E+008$

-----  
with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$f_c = 20.00$

$\alpha_1$  (5A.5, TBDY) = 0.002

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.0144353$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_c = 0.0144353$

where  $\mu_{cc}$  ((5.4c), TBDY) =  $\alpha_1 * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where  $f = \alpha_1 * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $\rho_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{fe} = 703.4155$

-----  
 $f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $\rho_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{fe} = 703.4155$

-----  
 $R = 40.00$

Effective FRP thickness,  $t_f = N_L * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{u,f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length

equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

-----  
 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.00298102$

$c$  = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$l_0/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$l_0/l_{ou,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , 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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_2 = fs = 299.3701$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$su_v = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$l_0/l_{ou,min} = l_b/l_d = 0.28304984$

$su_v = 0.4 * esuv_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv\_nominal}$  and  $y_v$ ,  $sh_v, ft_v, fy_v$ , it is considered characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{sv} = f_s = 299.3701$

with  $E_{sv} = E_s = 200000.00$

$$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03714718$$

$$2 = A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0782342$$

$$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06922883$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} \text{ (5A.2, TBDY)} = 21.96205$$

$$cc \text{ (5A.5, TBDY)} = 0.00298102$$

$c$  = confinement factor = 1.0981

$$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04362424$$

$$2 = A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09187529$$

$$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08129972$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u \text{ (4.9)} = 0.17212448$$

$$M_u = M_{Rc} \text{ (4.14)} = 2.1970E+008$$

$$u = s_u \text{ (4.1)} = 9.6917274E-006$$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Lap Length:  $l_b/l_d = 0.28304984$

$$l_b = 300.00$$

$$l_d = 1059.884$$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = 150.00$$

$$n = 16.00$$

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 424229.688$

$$V_{r1} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{CoI0}$$

$$V_{CoI0} = 424229.688$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

-----  
NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_{s+} = f \cdot V_f$ '

where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 47.23669$$

$$V_u = 0.00016213$$

$d = 0.8 \cdot h = 480.00$   
 $Nu = 8883.864$   
 $Ag = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 316483.206$   
 where:  
 $Vs1 = 93083.296$  is calculated for section web, with:  
 $d = 200.00$   
 $Av = 157079.633$   
 $fy = 444.44$   
 $s = 150.00$   
 $Vs1$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.75$   
 $Vs2 = 223399.91$  is calculated for section flange, with:  
 $d = 480.00$   
 $Av = 157079.633$   
 $fy = 444.44$   
 $s = 150.00$   
 $Vs2$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.3125$   
 $Vf$  ((11-3)-(11.4), ACI 440) = 293495.545  
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \csc \theta) \sin \alpha$  which is more a generalised expression,  
 where  $\theta$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $Vf(\theta, \alpha)$ , is implemented for every different fiber orientation  $\alpha_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = 90^\circ = 90.00$   
 $Vf = \text{Min}(|Vf(45, \alpha)|, |Vf(-45, \alpha)|)$ , with:  
 total thickness per orientation,  $tf1 = NL \cdot t / NoDir = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 557.00  
 $ffe$  ((11-5), ACI 440) = 259.312  
 $Ef = 64828.00$   
 $fe = 0.004$ , from (11.6a), ACI 440  
 with  $fu = 0.01$   
 From (11-11), ACI 440:  $Vs + Vf \leq 356502.845$   
 $bw = 250.00$

Calculation of Shear Strength at edge 2,  $Vr2 = 424229.688$   
 $Vr2 = VCol$  ((10.3), ASCE 41-17) =  $knl \cdot VCol0$   
 $VCol0 = 424229.688$   
 $knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $Vs$ ' is replaced by ' $Vs + f \cdot Vf$ '  
 where  $Vf$  is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$  (normal-weight concrete)  
 $fc' = 20.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $Mu = 47.23667$   
 $Vu = 0.00016213$   
 $d = 0.8 \cdot h = 480.00$   
 $Nu = 8883.864$   
 $Ag = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 316483.206$   
 where:  
 $Vs1 = 93083.296$  is calculated for section web, with:  
 $d = 200.00$   
 $Av = 157079.633$   
 $fy = 444.44$   
 $s = 150.00$   
 $Vs1$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.75$   
 $Vs2 = 223399.91$  is calculated for section flange, with:  
 $d = 480.00$   
 $Av = 157079.633$   
 $fy = 444.44$

s = 150.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.3125

Vf ((11-3)-(11.4), ACI 440) = 293495.545

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha)\sin \alpha$  which is more a generalised expression, where  $\theta$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(  $\theta$ ,  $\alpha$  ), 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:  $\theta = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45,  $\theta$ )|, |Vf(-45,  $\theta$ )|), with:

total thickness per orientation, tf1 = NL\*t/NoDir = 1.016

dfv = d (figure 11.2, ACI 440) = 557.00

ffe ((11-5), ACI 440) = 259.312

Ef = 64828.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.01

From (11-11), ACI 440: Vs + Vf <= 356502.845

bw = 250.00

-----  
End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At local axis: 2

-----  
Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rdcs

Constant Properties

-----  
Knowledge Factor,  $\gamma = 0.77$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00

Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity, Ec = 21019.039

Steel Elasticity, Es = 200000.00

Max Height, Hmax = 600.00

Min Height, Hmin = 250.00

Max Width, Wmax = 600.00

Min Width, Wmin = 250.00

Cover Thickness, c = 25.00

Element Length, L = 3000.00

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length lb = 300.00

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, t = 1.016

Tensile Strength, ffu = 1055.00

Tensile Modulus, Ef = 64828.00

Elongation, efu = 0.01

Number of directions, NoDir = 1

Fiber orientations, bi: 0.00°

Number of layers, NL = 1

Radius of rounding corners, R = 40.00

## Stepwise Properties

Bending Moment,  $M = -1.0749\text{E}+007$

Shear Force,  $V2 = -3536.316$

Shear Force,  $V3 = 123.1168$

Axial Force,  $F = -9530.256$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{s,ten} = 1746.726$

-Compression:  $A_{s,com} = 829.3805$

-Middle:  $A_{s,mid} = 1545.664$

Mean Diameter of Tension Reinforcement,  $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = u = 0.03779982$   
 $u = y + p = 0.04909067$

- Calculation of  $y$  -

$y = (M \cdot L_s / 3) / E_{eff} = 0.00709067$  ((4.29), Biskinis Phd))

$M_y = 2.9338\text{E}+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3039.544

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921\text{E}+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9530.256$

$E_c \cdot I_g = 1.3974\text{E}+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 4.0516275\text{E}-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 277.9106$

$d = 557.00$

$y = 0.38426988$

$A = 0.02984605$

$B = 0.01922829$

with  $pt = 0.01254381$

$pc = 0.00595605$

$pv = 0.01109992$

$N = 9530.256$

$b = 250.00$

$\rho = 0.07719928$

$y_{comp} = 8.1950430\text{E}-006$

with  $f_c^*$  (12.3, (ACI 440)) = 20.42407

$f_c = 20.00$

$f_l = 0.62098351$

$b = b_{max} = 600.00$

$h = h_{max} = 600.00$

$A_g = 237500.00$

$g = pt + pc + pv = 0.02959978$

$rc = 40.00$

$A_e / A_c = 0.21783041$

Effective FRP thickness,  $t_f = NL \cdot t \cdot \text{Cos}(b1) = 1.016$

effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$

$f_u = 0.01$

Ef = 64828.00  
Ec = 21019.039  
y = 0.38317351  
A = 0.02940413  
B = 0.01898202  
with Es = 200000.00

-----  
-----  
Calculation of ratio  $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.3538123$

$l_b = 300.00$

$l_d = 847.9072$

Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 18.00$

Mean strength value of all re-bars:  $f_y = 444.44$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

-----  
- Calculation of  $\rho$  -

From table 10-8:  $\rho = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/l_d \geq 1$

shear control ratio  $V_y E / V_{CoI} E = 0.62612363$

$d = 557.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1460.00$ , is the total Length of all stirrups parallel to loading (shear) direction

The term  $2 * t_f / b_w * (f_{fe} / f_s)$  is implemented to account for FRP contribution

where  $f = 2 * t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength

All these variables have already been given in Shear control ratio calculation.

$N_{UD} = 9530.256$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} = 0.00$

$\rho_l = \text{Area}_{Tot\_Long\_Rein} / (b * d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

-----  
End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

## Calculation No. 13

column C1, Floor 1

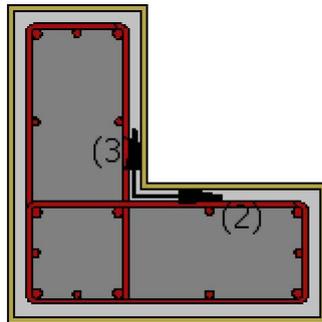
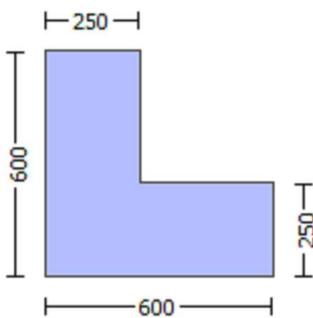
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$

Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$

Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -1.0749E+007$

Shear Force,  $V_a = -3536.316$

EDGE -B-

Bending Moment,  $M_b = 136240.323$

Shear Force,  $V_b = 3536.316$

BOTH EDGES

Axial Force,  $F = -9530.256$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1746.726$

-Compression:  $As_{l,com} = 829.3805$

-Middle:  $As_{l,mid} = 1545.664$

Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.71429$

-----  
Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 339055.351$

$V_n$  ((10.3), ASCE 41-17) =  $k_n \phi V_{Co10} = 440331.624$

$V_{Co10} = 440331.624$

$k_n = 1.00$

$displacement\_ductility\_demand = 0.05662636$

-----  
NOTE: In expression (10-3) 'Vs' is replaced by ' $V_{s+} = \phi V_f$ '  
where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

-----  
= 1 (normal-weight concrete)

$f_c' = 16.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/V_d = 2.00$

$M_u = 136240.323$

$V_u = 3536.316$

$d = 0.8 \cdot h = 480.00$

$N_u = 9530.256$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 284837.734$

where:

$V_{s1} = 83775.804$  is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.75$

$V_{s2} = 201061.93$  is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.3125$   
 $V_f((11-3)-(11.4), ACI 440) = 293495.545$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (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  $\theta$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL * t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 557.00  
 $f_{fe}((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 318865.838$   
 $bw = 250.00$

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  $\theta = 3.9629525E-005$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00069984$  ((4.29), Biskinis Phd)  
 $M_y = 2.9338E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 4.1921E+013$   
 $\text{factor} = 0.30$   
 $A_g = 237500.00$   
 $f_c' = 20.00$   
 $N = 9530.256$   
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.0516275E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 277.9106$   
 $d = 557.00$   
 $y = 0.38426988$   
 $A = 0.02984605$   
 $B = 0.01922829$   
 with  $p_t = 0.01254381$   
 $p_c = 0.00595605$   
 $p_v = 0.01109992$   
 $N = 9530.256$   
 $b = 250.00$   
 $\theta = 0.07719928$   
 $y_{comp} = 8.1950430E-006$   
 with  $f_c'((12.3), (ACI 440)) = 20.42407$   
 $f_c = 20.00$   
 $f_l = 0.62098351$   
 $b = b_{max} = 600.00$   
 $h = h_{max} = 600.00$   
 $A_g = 237500.00$   
 $g = p_t + p_c + p_v = 0.02959978$   
 $rc = 40.00$

$A_e/A_c = 0.21783041$   
Effective FRP thickness,  $t_f = NL*t*\text{Cos}(b1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 21019.039$   
 $y = 0.38317351$   
 $A = 0.02940413$   
 $B = 0.01898202$   
with  $E_s = 200000.00$

-----  
-----  
Calculation of ratio  $l_b/l_d$

Lap Length:  $l_d/l_{d,\min} = 0.3538123$

$l_b = 300.00$

$l_d = 847.9072$

Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars:  $f_y = 444.44$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

-----  
End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 14

column C1, Floor 1

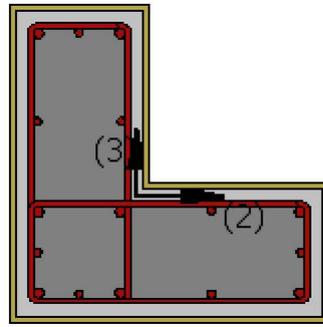
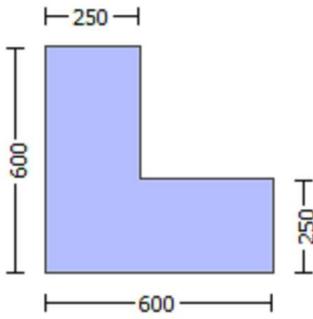
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3  
 (Bending local axis: 2)  
 Section Type: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$

#####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$

#####  
 Max Height,  $H_{max} = 600.00$   
 Min Height,  $H_{min} = 250.00$   
 Max Width,  $W_{max} = 600.00$   
 Min Width,  $W_{min} = 250.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.0981  
 Element Length,  $L = 3000.00$

Secondary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $e_{fu} = 0.01$   
 Number of directions,  $NoDir = 1$   
 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,  $V_a = 0.00016213$   
 EDGE -B-  
 Shear Force,  $V_b = -0.00016213$

BOTH EDGES

Axial Force,  $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{,ten} = 1746.726$

-Compression:  $As_{,com} = 829.3805$

-Middle:  $As_{,mid} = 1545.664$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.62612363$

Member Controlled by Flexure ( $V_e/V_r < 1$ )

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.9843E+008$

$Mu_{1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.9843E+008$

$Mu_{2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$Mu_{2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of  $Mu_{1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.1848408E-005$

$M_u = 3.9843E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

$\omega (5A.5, \text{TBDY}) = 0.002$

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.0144353$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.0144353$

where  $\phi_u (5.4c, \text{TBDY}) = a_s e^* \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07473805$

where  $\phi = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.24098246$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 57233.333$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{fe} = 703.4155$

$\phi_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.24098246$

with Unconfined area =  $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 0.00$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

From EC8 A.4.3(6),  $pf = 2t_f/bw = 0.008128$   
 $bw = 250.00$   
effective stress from (A.35),  $ff_e = 703.4155$

$R = 40.00$   
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$   
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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00321875$

Expression ((5.4d), TBDY) for  $psh_{,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along Y) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along X) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

$s = 150.00$   
 $f_{ywe} = 555.55$   
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$

$y_1 = 0.00124738$   
 $sh_1 = 0.00431097$   
 $ft_1 = 359.2441$   
 $fy_1 = 299.3701$   
 $su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $fy_2 = 299.3701$   
 $su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $es_{u2\_nominal}$  and  $y_2$ ,  $sh_2, ft_2, fy_2$ , 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, ASCE41-17.

with  $fs_2 = fs = 299.3701$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$s_{uv} = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.28304984$

$s_{uv} = 0.4 \cdot es_{uv\_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $es_{uv\_nominal} = 0.08$ ,

considering characteristic value  $fs_{yv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $es_{uv\_nominal}$  and  $y_v$ ,  $sh_v, ft_v, fy_v$ , it is considered characteristic value  $fs_{yv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{sv} = fs = 299.3701$

with  $Es_v = Es = 200000.00$

1 =  $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.18776209$

2 =  $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08915322$

v =  $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.16614919$

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

$f_{cc} (5A.2, TBDY) = 21.96205$

$cc (5A.5, TBDY) = 0.00298102$

c = confinement factor = 1.0981

1 =  $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.26111925$

2 =  $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12398468$

v =  $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.23106236$

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

--->

$s_u (4.8) = 0.32281672$

$\mu_u = MR_c (4.15) = 3.9843E+008$

u =  $s_u (4.1) = 1.1848408E-005$

-----  
Calculation of ratio  $lb/ld$

-----  
Lap Length:  $lb/ld = 0.28304984$

$lb = 300.00$

$ld = 1059.884$

Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars:  $f_y = 555.55$

$f'_c = 20.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 157.0796$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

s = 150.00

n = 16.00

Calculation of Mu1-

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.6917274E-006$$

$$Mu = 2.1970E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,\min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir\*Astir/(Asec\*s) = 0.00321875  
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00  
fywe = 555.55  
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102  
c = confinement factor = 1.0981

y1 = 0.00124738  
sh1 = 0.00431097  
ft1 = 359.2441  
fy1 = 299.3701  
su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.28304984

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738  
sh2 = 0.00431097  
ft2 = 359.2441  
fy2 = 299.3701  
su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738  
shv = 0.00431097  
ftv = 359.2441  
fyv = 299.3701  
suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.28304984

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.03714718

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0782342

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.06922883

and confined core properties:

b = 540.00

$d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04362424$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09187529$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08129972$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.17212448$   
 $Mu = MRc (4.14) = 2.1970E+008$   
 $u = su (4.1) = 9.6917274E-006$

-----  
 Calculation of ratio  $l_b/l_d$

-----  
 Lap Length:  $l_b/l_d = 0.28304984$   
 $l_b = 300.00$   
 $l_d = 1059.884$   
 Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 18.00$   
 Mean strength value of all re-bars:  $f_y = 555.55$   
 $f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.61799$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$   
 where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = 150.00$   
 $n = 16.00$

-----  
 Calculation of  $Mu_{2+}$

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 1.1848408E-005$   
 $Mu = 3.9843E+008$

-----  
 with full section properties:

$b = 250.00$   
 $d = 557.00$   
 $d' = 43.00$   
 $v = 0.00318999$   
 $N = 8883.864$   
 $f_c = 20.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.0144353$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.0144353$   
 $we ((5.4c), TBDY) = ase^* sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$   
 where  $f = af * \rho_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)  
 -----  
 $f_x = 0.06888919$   
 Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
 $af = 0.24098246$   
 with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$   
 $b_{max} = 600.00$

hmax = 600.00  
From EC8 A 4.4.3(6),  $pf = 2tf/bw = 0.008128$   
bw = 250.00  
effective stress from (A.35),  $ff,e = 703.4155$

fy = 0.06888919  
Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
af = 0.24098246  
with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$   
bmax = 600.00  
hmax = 600.00  
From EC8 A 4.4.3(6),  $pf = 2tf/bw = 0.008128$   
bw = 250.00  
effective stress from (A.35),  $ff,e = 703.4155$

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 =  $Max(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.21805635$   
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.  
 $A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.  
 $A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.  
 $A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).  
 $psh,min = Min(psh,x, psh,y) = 0.00321875$   
Expression ((5.4d), TBDY) for  $psh,min$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x$  ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$   
Lstir (Length of stirrups along Y) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

$psh,y$  ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$   
Lstir (Length of stirrups along X) = 1460.00  
Astir (stirrups area) = 78.53982  
Asec (section area) = 237500.00

s = 150.00  
fywe = 555.55  
fce = 20.00  
From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$   
c = confinement factor = 1.0981  
y1 = 0.00124738  
sh1 = 0.00431097  
ft1 = 359.2441  
fy1 = 299.3701  
su1 = 0.00446911  
using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00  
 $lo/lou,min = lb/d = 0.28304984$   
 $su1 = 0.4*esu1\_nominal$  ((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, ASCE41-17.  
with  $fs1 = fs = 299.3701$   
with  $Es1 = Es = 200000.00$

y2 = 0.00124738  
sh2 = 0.00431097  
ft2 = 359.2441  
fy2 = 299.3701  
su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

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, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738  
shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.28304984

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.18776209

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.08915322

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.16614919

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.26111925

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.12398468

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.23106236

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) = 0.32281672

Mu = MRc (4.15) = 3.9843E+008

u = su (4.1) = 1.1848408E-005

-----  
Calculation of ratio lb/ld

-----  
Lap Length: lb/ld = 0.28304984

lb = 300.00

ld = 1059.884

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

-----  
Calculation of  $\mu_2$ -  
-----

-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.6917274E-006$

$M_u = 2.1970E+008$

-----  
with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$f_c = 20.00$

$\alpha_1(5A.5, \text{TBDY}) = 0.002$

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.0144353$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_c = 0.0144353$

where  $\mu_{cc}$  ((5.4c), TBDY) =  $\alpha_1 s_e \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where  $f = \alpha_1 \cdot p_f \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{fe} = 703.4155$

-----  
 $f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{fe} = 703.4155$

-----  
 $R = 40.00$

Effective FRP thickness,  $t_f = N L^* t \cos(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length

equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

-----  
 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.00298102$

$c$  = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered

characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , 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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_2 = fs = 299.3701$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$su_v = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_v = 0.4 * esuv_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $e_{suv\_nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{sv} = f_s = 299.3701$

with  $E_{sv} = E_s = 200000.00$

1 =  $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03714718$

2 =  $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0782342$

v =  $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06922883$

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

$f_{cc}$  (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

1 =  $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04362424$

2 =  $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09187529$

v =  $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08129972$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v <  $v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.17212448

Mu = MRc (4.14) = 2.1970E+008

u = su (4.1) = 9.6917274E-006

-----  
Calculation of ratio  $l_b/l_d$

-----  
Lap Length:  $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars:  $f_y = 555.55$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.61799

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

s = 150.00

n = 16.00

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 424229.688$

$V_{r1} = V_{CoI}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{CoI0}$

$V_{CoI0} = 424229.688$

$k_{nl} = 1$  (zero step-static loading)

-----  
NOTE: In expression (10-3) ' $V_s$ ' 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)

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 47.24078

Vu = 0.00016213

$d = 0.8 \cdot h = 480.00$   
 $Nu = 8883.864$   
 $Ag = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 316483.206$   
 where:  
 $Vs1 = 223399.91$  is calculated for section web, with:  
 $d = 480.00$   
 $Av = 157079.633$   
 $fy = 444.44$   
 $s = 150.00$   
 $Vs1$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $Vs2 = 93083.296$  is calculated for section flange, with:  
 $d = 200.00$   
 $Av = 157079.633$   
 $fy = 444.44$   
 $s = 150.00$   
 $Vs2$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $Vf$  ((11-3)-(11.4), ACI 440) = 293495.545  
 $f = 0.95$ , 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  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a = b1 + 90^\circ = 90.00$   
 $Vf = \text{Min}(|Vf(45, 1)|, |Vf(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL \cdot t / NoDir = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 557.00  
 $ffe$  ((11-5), ACI 440) = 259.312  
 $Ef = 64828.00$   
 $fe = 0.004$ , from (11.6a), ACI 440  
 with  $fu = 0.01$   
 From (11-11), ACI 440:  $Vs + Vf \leq 356502.845$   
 $bw = 250.00$

Calculation of Shear Strength at edge 2,  $Vr2 = 424229.688$   
 $Vr2 = VCol$  ((10.3), ASCE 41-17) =  $knl \cdot VCol0$   
 $VCol0 = 424229.688$   
 $knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf'  
 where Vf is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$  (normal-weight concrete)  
 $fc' = 20.00$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $Mu = 47.24081$   
 $Vu = 0.00016213$   
 $d = 0.8 \cdot h = 480.00$   
 $Nu = 8883.864$   
 $Ag = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 316483.206$   
 where:  
 $Vs1 = 223399.91$  is calculated for section web, with:  
 $d = 480.00$   
 $Av = 157079.633$   
 $fy = 444.44$   
 $s = 150.00$   
 $Vs1$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.3125$   
 $Vs2 = 93083.296$  is calculated for section flange, with:  
 $d = 200.00$   
 $Av = 157079.633$   
 $fy = 444.44$

$s = 150.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.75$   
 $V_f((11-3)-(11.4), ACI 440) = 293495.545$   
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $\theta$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL * t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 557.00  
 $f_{fe}((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 356502.845$   
 $bw = 250.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At local axis: 3  
 -----

-----  
 Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rdcs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 0.77$   
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$   
 Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Existing material: Steel Strength,  $f_s = 1.25 * f_{sm} = 555.55$   
 #####  
 Max Height,  $H_{max} = 600.00$   
 Min Height,  $H_{min} = 250.00$   
 Max Width,  $W_{max} = 600.00$   
 Min Width,  $W_{min} = 250.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.0981  
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_o = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $e_{fu} = 0.01$

Number of directions, 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 = 0.00016213  
EDGE -B-  
Shear Force, Vb = -0.00016213  
BOTH EDGES  
Axial Force, F = -8883.864  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 4121.77  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 1746.726  
-Compression: Asl,com = 829.3805  
-Middle: Asl,mid = 1545.664  
-----  
-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.62612363$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$   
with  
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.9843E+008$   
 $\mu_{1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
which is defined for the static loading combination  
 $\mu_{1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.9843E+008$   
 $\mu_{2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
which is defined for the the static loading combination  
 $\mu_{2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment  
direction which is defined for the the static loading combination

-----  
Calculation of  $\mu_{1+}$   
-----

-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.1848408E-005$

$M_u = 3.9843E+008$   
-----

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00318999$

$N = 8883.864$

$f_c = 20.00$

$\alpha (5A.5, \text{TBDY}) = 0.002$

Final value of  $\mu_c$ :  $\mu_c^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.0144353$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_c = 0.0144353$

where  $\mu_{cc}$  ((5.4c), TBDY) =  $\alpha s_e * s_{h,\text{min}} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where  $f = \alpha f_p^* f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $\alpha f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha f = 0.24098246$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35),  $ff,e = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.24098246$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35),  $ff,e = 703.4155$

$R = 40.00$

Effective FRP thickness,  $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$  ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

$p_{sh,y}$  ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c$  = confinement factor = 1.0981

$y1 = 0.00124738$

$sh1 = 0.00431097$

$ft1 = 359.2441$

$fy1 = 299.3701$

$su1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lou,min = lb/ld = 0.28304984$

$su1 = 0.4*esu1_{nominal}$  ((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, ASCE41-17.

with  $f_{s1} = f_s = 299.3701$   
 with  $E_{s1} = E_s = 200000.00$   
 $y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $fy_2 = 299.3701$   
 $su_2 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_0/l_{ou,min} = l_b/l_{b,min} = 0.28304984$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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, ASCE41-17.  
 with  $f_{s2} = f_s = 299.3701$   
 with  $E_{s2} = E_s = 200000.00$   
 $y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $fy_v = 299.3701$   
 $su_v = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_0/l_{ou,min} = l_b/l_d = 0.28304984$   
 $su_v = 0.4 * esu_{v,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{v,nominal} = 0.08$ ,  
 considering characteristic value  $fsy_v = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $esu_{v,nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsy_v = f_{sv}/1.2$ , 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, ASCE41-17.  
 with  $f_{sv} = f_s = 299.3701$   
 with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.18776209$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08915322$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.16614919$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$   
 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  
 --->  
 $su (4.8) = 0.32281672$   
 $Mu = MR_c (4.15) = 3.9843E+008$   
 $u = su (4.1) = 1.1848408E-005$

-----  
 Calculation of ratio  $l_b/l_d$   
 -----

Lap Length:  $l_b/l_d = 0.28304984$   
 $l_b = 300.00$   
 $l_d = 1059.884$   
 Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 = 1

db = 18.00

Mean strength value of all re-bars:  $f_y = 555.55$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.61799

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

s = 150.00

n = 16.00

-----  
-----  
-----  
Calculation of  $\mu_1$ -

-----  
-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.6917274E-006$

$\mu_1 = 2.1970E+008$

-----  
with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

$f_c = 20.00$

$\alpha$  (5A.5, TBDY) = 0.002

Final value of  $\mu$ :  $\mu^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_s) = 0.0144353$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_c = 0.0144353$

where  $\mu_s$  ((5.4c), TBDY) =  $\alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where  $f = \alpha * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

-----  
 $f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

-----  
R = 40.00

Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $p_{sh,x}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

-----  
 $p_{sh,y}$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c = \text{confinement factor} = 1.0981$

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_0/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 * esu_{1,nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_0/l_{ou,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 * esu_{2,nominal}$  ((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  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_2 = fs = 299.3701$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$su_v = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_0/l_{ou,min} = l_b/l_d = 0.28304984$

$$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv\_nominal$  and  $yv$ ,  $shv,ftv,fyv$ , it is considered characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1, sh1,ft1,fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 299.3701$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 21.96205$$

$$cc (5A.5, TBDY) = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

$v < vs,y2$  - LHS eq.(4.5) is satisfied

---

$$su (4.9) = 0.17212448$$

$$Mu = MRc (4.14) = 2.1970E+008$$

$$u = su (4.1) = 9.6917274E-006$$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.28304984$

$$lb = 300.00$$

$$ld = 1059.884$$

Calculation of  $lb,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars:  $fy = 555.55$

$$fc' = 20.00, \text{ but } fc'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 2.61799$$

$$Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$$

where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = 150.00$$

$$n = 16.00$$

Calculation of  $Mu2+$

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.1848408E-005$$

$$Mu = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$\text{we ((5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$f_{y1} = 299.3701$   
 $s_{u1} = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.28304984$   
 $s_{u1} = 0.4 * e_{su1,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{su1,nominal} = 0.08$ ,  
 For calculation of  $e_{su1,nominal}$  and  $y_1, sh_1, ft_1, f_{y1}$ , it is considered  
 characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{s1} = f_s = 299.3701$   
 with  $E_{s1} = E_s = 200000.00$   
 $y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $f_{y2} = 299.3701$   
 $s_{u2} = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$   
 $s_{u2} = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{su2,nominal} = 0.08$ ,  
 For calculation of  $e_{su2,nominal}$  and  $y_2, sh_2, ft_2, f_{y2}$ , it is considered  
 characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.  
 $y_2, sh_2, ft_2, f_{y2}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{s2} = f_s = 299.3701$   
 with  $E_{s2} = E_s = 200000.00$   
 $y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $f_{yv} = 299.3701$   
 $s_{uv} = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.28304984$   
 $s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{suv,nominal} = 0.08$ ,  
 considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $e_{suv,nominal}$  and  $y_v, sh_v, ft_v, f_{yv}$ , it is considered  
 characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{sv} = f_s = 299.3701$   
 with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.18776209$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08915322$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.16614919$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$   
 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  
 --->  
 $su (4.8) = 0.32281672$

$$\begin{aligned} \mu_u &= M/R_c(4.15) = 3.9843E+008 \\ u &= s_u(4.1) = 1.1848408E-005 \end{aligned}$$

-----  
Calculation of ratio  $l_b/l_d$   
-----

$$\begin{aligned} \text{Lap Length: } l_b/l_d &= 0.28304984 \\ l_b &= 300.00 \\ l_d &= 1059.884 \end{aligned}$$

Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

$$\begin{aligned} d_b &= 18.00 \\ \text{Mean strength value of all re-bars: } f_y &= 555.55 \\ f_c' &= 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)} \\ t &= 1.00 \\ s &= 0.80 \\ e &= 1.00 \\ c_b &= 25.00 \\ K_{tr} &= 2.61799 \\ A_{tr} &= \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796 \\ &\text{where } A_{tr_x}, A_{tr_y} \text{ are the sum of the area of all stirrup legs along X and Y local axis} \\ s &= 150.00 \\ n &= 16.00 \end{aligned}$$

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-----  
Calculation of  $\mu_u$   
-----

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$\begin{aligned} u &= 9.6917274E-006 \\ \mu_u &= 2.1970E+008 \end{aligned}$$

-----  
with full section properties:

$$\begin{aligned} b &= 600.00 \\ d &= 557.00 \\ d' &= 43.00 \\ v &= 0.00132912 \\ N &= 8883.864 \\ f_c &= 20.00 \\ c_o \text{ (5A.5, TBDY)} &= 0.002 \\ \text{Final value of } c_u: c_u^* &= \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353 \\ &\text{The Shear\_factor is considered equal to 1 (pure moment strength)} \\ \text{From (5.4b), TBDY: } c_u &= 0.0144353 \\ v_e \text{ ((5.4c), TBDY)} &= a_s e * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805 \\ \text{where } f &= a_f * p_f * f_{fe} / f_{ce} \text{ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)} \end{aligned}$$

-----

$$\begin{aligned} f_x &= 0.06888919 \\ \text{Expression ((15B.6), TBDY) is modified as } a_f &= 1 - (\text{Unconfined area}) / (\text{total area}) \\ a_f &= 0.24098246 \\ \text{with Unconfined area} &= ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333 \\ b_{\max} &= 600.00 \\ h_{\max} &= 600.00 \\ \text{From EC8 A.4.4.3(6), } p_f &= 2t_f / b_w = 0.008128 \\ b_w &= 250.00 \\ \text{effective stress from (A.35), } f_{f,e} &= 703.4155 \end{aligned}$$

-----

$$\begin{aligned} f_y &= 0.06888919 \\ \text{Expression ((15B.6), TBDY) is modified as } a_f &= 1 - (\text{Unconfined area}) / (\text{total area}) \\ a_f &= 0.24098246 \\ \text{with Unconfined area} &= ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00 \\ b_{\max} &= 600.00 \\ h_{\max} &= 600.00 \\ \text{From EC8 A.4.4.3(6), } p_f &= 2t_f / b_w = 0.008128 \\ b_w &= 250.00 \\ \text{effective stress from (A.35), } f_{f,e} &= 703.4155 \end{aligned}$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$$fy_1 = 299.3701$$

$$su_1 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o / l_{o,min} = l_b / l_d = 0.28304984$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 299.3701$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00124738$$

$$sh_2 = 0.00431097$$

$$ft_2 = 359.2441$$

$$fy_2 = 299.3701$$

$$su_2 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o / l_{o,min} = l_b / l_{b,min} = 0.28304984$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,

For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{s2} = f_s = 299.3701$   
 with  $E_{s2} = E_s = 200000.00$   
 $y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $fy_v = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.28304984$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{sv} = f_s = 299.3701$   
 with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.03714718$   
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.0782342$   
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.06922883$

and confined core properties:

$b = 540.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.04362424$   
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09187529$   
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.08129972$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

---

$su (4.9) = 0.17212448$   
 $Mu = MRc (4.14) = 2.1970E+008$   
 $u = su (4.1) = 9.6917274E-006$

-----  
 Calculation of ratio  $l_b/l_d$   
 -----

Lap Length:  $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$   
 $db = 18.00$   
 Mean strength value of all re-bars:  $f_y = 555.55$   
 $f'_c = 20.00$ , but  $f'_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.61799$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$   
 where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = 150.00$   
 $n = 16.00$

-----  
 Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$   
 -----

Calculation of Shear Strength at edge 1,  $Vr1 = 424229.688$

$Vr1 = VCol$  ((10.3), ASCE 41-17) =  $knl * VColO$

$VColO = 424229.688$

$knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$fc' = 20.00$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 47.23669$

$Vu = 0.00016213$

$d = 0.8 * h = 480.00$

$Nu = 8883.864$

$Ag = 150000.00$

From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 316483.206$

where:

$Vs1 = 93083.296$  is calculated for section web, with:

$d = 200.00$

$Av = 157079.633$

$fy = 444.44$

$s = 150.00$

$Vs1$  is multiplied by  $Col1 = 1.00$

$s/d = 0.75$

$Vs2 = 223399.91$  is calculated for section flange, with:

$d = 480.00$

$Av = 157079.633$

$fy = 444.44$

$s = 150.00$

$Vs2$  is multiplied by  $Col2 = 1.00$

$s/d = 0.3125$

$Vf$  ((11-3)-(11.4), ACI 440) =  $293495.545$

$f = 0.95$ , for fully-wrapped sections

$wf/sf = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $Vf(a, \dots)$ , is implemented for every different cyclic 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:  $\theta = b1 + 90^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$ , with:

total thickness per orientation,  $tf1 = NL * t / \text{NoDir} = 1.016$

$dfv = d$  (figure 11.2, ACI 440) =  $557.00$

$ffe$  ((11-5), ACI 440) =  $259.312$

$Ef = 64828.00$

$fe = 0.004$ , from (11.6a), ACI 440

with  $fu = 0.01$

From (11-11), ACI 440:  $Vs + Vf \leq 356502.845$

$bw = 250.00$

Calculation of Shear Strength at edge 2,  $Vr2 = 424229.688$

$Vr2 = VCol$  ((10.3), ASCE 41-17) =  $knl * VColO$

$VColO = 424229.688$

$knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$fc' = 20.00$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 47.23667$

$Vu = 0.00016213$

$d = 0.8 * h = 480.00$

$Nu = 8883.864$

$Ag = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 93083.296$  is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.75$

$V_{s2} = 223399.91$  is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.3125$

$V_f$  ((11-3)-(11.4), ACI 440) = 293495.545

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 557.00

$f_{fe}$  ((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:  $V_s + V_f \leq 356502.845$

$b_w = 250.00$

-----  
End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At local axis: 2

-----  
Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rclcs

Constant Properties

-----  
Knowledge Factor,  $\phi = 0.77$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_b = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -101614.073$   
Shear Force,  $V_2 = 3536.316$   
Shear Force,  $V_3 = -123.1168$   
Axial Force,  $F = -9530.256$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 4121.77$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1746.726$   
-Compression:  $A_{sl,com} = 829.3805$   
-Middle:  $A_{sl,mid} = 1545.664$   
Mean Diameter of Tension Reinforcement,  $D_bL = 17.71429$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = * u = 0.03382254$   
 $u = y + p = 0.04392538$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00192538$  ((4.29), Biskinis Phd)  
 $M_y = 2.9338E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 825.3468  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 4.1921E+013$   
factor = 0.30  
 $A_g = 237500.00$   
 $f_c' = 20.00$   
 $N = 9530.256$   
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.0516275E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 277.9106$   
 $d = 557.00$   
 $y = 0.38426988$   
 $A = 0.02984605$   
 $B = 0.01922829$   
with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9530.256$   
 $b = 250.00$   
 $" = 0.07719928$

$y_{comp} = 8.1950430E-006$   
 with  $f_c^*$  (12.3, (ACI 440)) = 20.42407  
 $f_c = 20.00$   
 $f_l = 0.62098351$   
 $b = b_{max} = 600.00$   
 $h = h_{max} = 600.00$   
 $A_g = 237500.00$   
 $g = p_t + p_c + p_v = 0.02959978$   
 $r_c = 40.00$   
 $A_e/A_c = 0.21783041$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 21019.039$   
 $y = 0.38317351$   
 $A = 0.02940413$   
 $B = 0.01898202$   
 with  $E_s = 200000.00$

-----  
 Calculation of ratio  $l_b/d$   
 -----

Lap Length:  $l_d/l_{d,min} = 0.3538123$

$l_b = 300.00$

$l_d = 847.9072$

Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 18.00$

Mean strength value of all re-bars:  $f_y = 444.44$

$f_c' = 20.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

-----  
 - Calculation of  $p$  -  
 -----

From table 10-8:  $p = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because  $l_b/d \geq 1$

shear control ratio  $V_y E / V_{CoI} E = 0.62612363$

$d = 557.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$ , is the area of every stirrup

$L_{stir} = 1460.00$ , is the total Length of all stirrups parallel to loading (shear) direction

The term  $2 * t_f / b_w * (f_{fe} / f_s)$  is implemented to account for FRP contribution

where  $f = 2 * t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength

All these variables have already been given in Shear control ratio calculation.

$NUD = 9530.256$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$p_l = \text{Area\_Tot\_Long\_Rein} / (b * d) = 0.02959978$

$b = 250.00$

$d = 557.00$

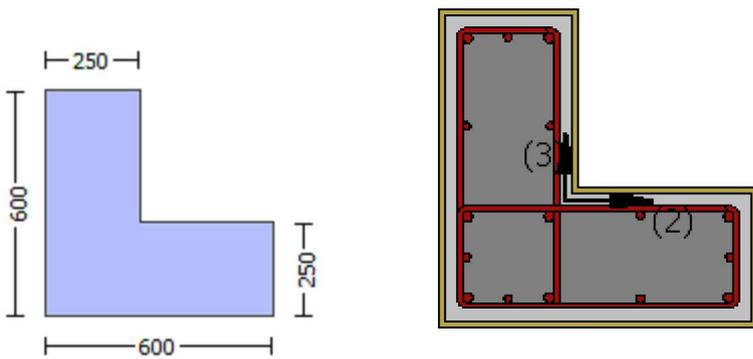
$f_{cE} = 20.00$

-----  
 End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2  
Integration Section: (b)

## Calculation No. 15

column C1, Floor 1  
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)  
Analysis: Uniform +X  
Check: Shear capacity VRd  
Edge: End  
Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1  
At local axis: 3  
Integration Section: (b)  
Section Type: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$   
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.  
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:  
Existing material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$   
Existing material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$   
Concrete Elasticity,  $E_c = 21019.039$   
Steel Elasticity,  $E_s = 200000.00$

#####  
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,  
the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as  
Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
#####

Max Height, Hmax = 600.00  
Min Height, Hmin = 250.00  
Max Width, Wmax = 600.00  
Min Width, Wmin = 250.00  
Cover Thickness, c = 25.00  
Element Length, L = 3000.00  
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length lo = lb = 300.00  
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness, t = 1.016  
Tensile Strength, ffu = 1055.00  
Tensile Modulus, Ef = 64828.00  
Elongation, efu = 0.01  
Number of directions, NoDir = 1  
Fiber orientations, bi: 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

#### Stepwise Properties

EDGE -A-  
Bending Moment, Ma = -266395.829  
Shear Force, Va = 123.1168  
EDGE -B-  
Bending Moment, Mb = -101614.073  
Shear Force, Vb = -123.1168  
BOTH EDGES  
Axial Force, F = -9530.256  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 4121.77  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 1746.726  
-Compression: Asl,com = 829.3805  
-Middle: Asl,mid = 1545.664  
Mean Diameter of Tension Reinforcement, DbL,ten = 17.71429

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity VR = \*Vn = 339055.351  
Vn ((10.3), ASCE 41-17) = knl\*VCol0 = 440331.624  
VCol = 440331.624  
knl = 1.00  
displacement\_ductility\_demand = 1.1629571E-005

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*VF'  
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)  
fc' = 16.00, but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
M/Vd = 2.00  
Mu = 101614.073  
Vu = 123.1168  
d = 0.8\*h = 480.00  
Nu = 9530.256  
Ag = 150000.00  
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 284837.734  
where:  
Vs1 = 201061.93 is calculated for section web, with:

$d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 150.00$   
 Vs1 is multiplied by Col1 = 1.00  
 $s/d = 0.3125$   
 Vs2 = 83775.804 is calculated for section flange, with:  
 $d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 400.00$   
 $s = 150.00$   
 Vs2 is multiplied by Col2 = 1.00  
 $s/d = 0.75$   
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 557.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 318865.838$   
 $b_w = 250.00$

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  $\theta = 2.2391291E-008$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00192538$  ((4.29), Biskinis Phd)  
 $M_y = 2.9338E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 825.3468  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 4.1921E+013$   
 $\text{factor} = 0.30$   
 $A_g = 237500.00$   
 $f_c' = 20.00$   
 $N = 9530.256$   
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 4.0516275E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 277.9106$   
 $d = 557.00$   
 $y = 0.38426988$   
 $A = 0.02984605$   
 $B = 0.01922829$   
 with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9530.256$   
 $b = 250.00$

" = 0.07719928  
y\_comp = 8.1950430E-006  
with  $f_c^*$  (12.3, (ACI 440)) = 20.42407  
fc = 20.00  
fl = 0.62098351  
b = bmax = 600.00  
h = hmax = 600.00  
Ag = 237500.00  
g = pt + pc + pv = 0.02959978  
rc = 40.00  
Ae/Ac = 0.21783041  
Effective FRP thickness,  $t_f = NL * t * \cos(b1) = 1.016$   
effective strain from (12.5) and (12.12),  $e_{fe} = 0.004$   
fu = 0.01  
Ef = 64828.00  
Ec = 21019.039  
y = 0.38317351  
A = 0.02940413  
B = 0.01898202  
with Es = 200000.00

-----  
-----  
Calculation of ratio  $l_b/l_d$

-----  
Lap Length:  $l_d/l_{d,min} = 0.3538123$

lb = 300.00

ld = 847.9072

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars:  $f_y = 444.44$

$f_c' = 20.00$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.61799

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

s = 150.00

n = 16.00

-----  
End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

-----  
**Calculation No. 16**

column C1, Floor 1

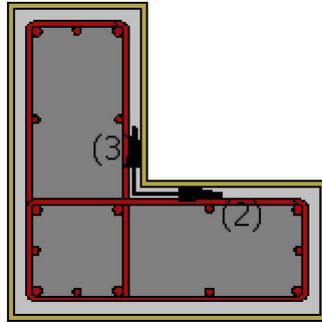
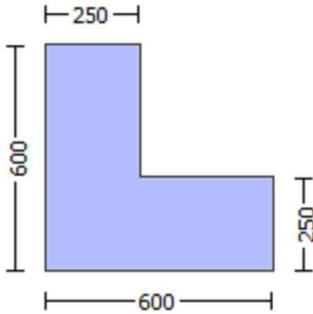
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta_r$ )

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rclcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length  $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

Number of directions, NoDir = 1  
Fiber orientations, bi: 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

-----  
Stepwise Properties  
-----

At local axis: 3  
EDGE -A-  
Shear Force, Va = 0.00016213  
EDGE -B-  
Shear Force, Vb = -0.00016213  
BOTH EDGES  
Axial Force, F = -8883.864  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension: Aslt = 0.00  
-Compression: Aslc = 4121.77  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension: Asl,ten = 1746.726  
-Compression: Asl,com = 829.3805  
-Middle: Asl,mid = 1545.664

-----  
Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.62612363$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with  
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.9843E+008$   
 $\mu_{1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $\mu_{1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.9843E+008$   
 $\mu_{2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $\mu_{2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

-----  
Calculation of  $\mu_{1+}$   
-----

-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.1848408E-005$

$\mu_u = 3.9843E+008$

-----  
with full section properties:

b = 250.00

d = 557.00

d' = 43.00

v = 0.00318999

N = 8883.864

f<sub>c</sub> = 20.00

co (5A.5, TBDY) = 0.002

Final value of  $\mu_c$ :  $\mu_c^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.0144353$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_c = 0.0144353$

$\mu_{we}$  ((5.4c), TBDY) =  $a_s e^* \text{sh}_{,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where  $f = a_f * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.24098246$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35),  $ff,e = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.24098246$

with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35),  $ff,e = 703.4155$

$R = 40.00$

Effective FRP thickness,  $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$  ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

$p_{sh,y}$  ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c$  = confinement factor = 1.0981

$y1 = 0.00124738$

$sh1 = 0.00431097$

$ft1 = 359.2441$

$fy1 = 299.3701$

$su1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lou,min = lb/ld = 0.28304984$

$su1 = 0.4*esu1_{nominal}$  ((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, ASCE41-17.

with  $f_{s1} = f_s = 299.3701$   
 with  $E_{s1} = E_s = 200000.00$   
 $y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $fy_2 = 299.3701$   
 $su_2 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 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, ASCE41-17.  
 with  $f_{s2} = f_s = 299.3701$   
 with  $E_{s2} = E_s = 200000.00$   
 $y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $fy_v = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.28304984$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsy_v = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fsy_v = f_{sv}/1.2$ , 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, ASCE41-17.  
 with  $f_{sv} = f_s = 299.3701$   
 with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.18776209$   
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.08915322$   
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.16614919$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.26111925$   
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.12398468$   
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.23106236$   
 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  
 --->  
 $su (4.8) = 0.32281672$   
 $Mu = MR_c (4.15) = 3.9843E+008$   
 $u = su (4.1) = 1.1848408E-005$

-----  
 Calculation of ratio  $l_b/l_d$   
 -----

Lap Length:  $l_b/l_d = 0.28304984$   
 $l_b = 300.00$   
 $l_d = 1059.884$   
 Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 = 1

db = 18.00

Mean strength value of all re-bars:  $f_y = 555.55$

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.61799

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

s = 150.00

n = 16.00

-----  
-----  
-----  
Calculation of  $\mu_1$ -

-----  
-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.6917274E-006$

$\mu_u = 2.1970E+008$

-----  
with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

$f_c = 20.00$

$\alpha$  (5A.5, TBDY) = 0.002

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.0144353$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.0144353$

where  $\mu_c$  ((5.4c), TBDY) =  $\alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where  $f = \alpha f_p * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

-----  
 $f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.24098246$

with Unconfined area =  $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35),  $f_{f,e} = 703.4155$

-----  
R = 40.00

Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00321875$

Expression ((5.4d), TBDY) for  $psh_{min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_x$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along Y) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

-----  
 $psh_y$  ((5.4d), TBDY) =  $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

$L_{stir}$  (Length of stirrups along X) = 1460.00

$A_{stir}$  (stirrups area) = 78.53982

$A_{sec}$  (section area) = 237500.00

-----  
 $s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$

$c = \text{confinement factor} = 1.0981$

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{min} = lb/ld = 0.28304984$

$su_1 = 0.4 * esu_{1\_nominal}$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY:  $esu_{1\_nominal} = 0.08$ ,

For calculation of  $esu_{1\_nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{min} = lb/lb_{min} = 0.28304984$

$su_2 = 0.4 * esu_{2\_nominal}$  ((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  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_2 = fs = 299.3701$

with  $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$su_v = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{min} = lb/ld = 0.28304984$

$$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv\_nominal$  and  $yv$ ,  $shv,ftv,fyv$ , it is considered characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1, sh1,ft1,fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 299.3701$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 21.96205$$

$$cc (5A.5, TBDY) = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$  - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.17212448$$

$$Mu = MRc (4.14) = 2.1970E+008$$

$$u = su (4.1) = 9.6917274E-006$$

-----  
Calculation of ratio  $lb/ld$

-----  
Lap Length:  $lb/ld = 0.28304984$

$$lb = 300.00$$

$$ld = 1059.884$$

Calculation of  $lb,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars:  $fy = 555.55$

$fc' = 20.00$ , but  $fc'^{0.5} <= 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 2.61799$$

$$Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$$

where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis

$$s = 150.00$$

$$n = 16.00$$

-----  
Calculation of  $Mu2+$

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.1848408E-005$$

$$Mu = 3.9843E+008$$

-----  
with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$\text{we ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$f_{y1} = 299.3701$   
 $s_{u1} = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.28304984$   
 $s_{u1} = 0.4 * e_{s1\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{s1\_nominal} = 0.08$ ,  
 For calculation of  $e_{s1\_nominal}$  and  $y_1, sh_1, ft_1, f_{y1}$ , it is considered  
 characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{s1} = f_s = 299.3701$   
 with  $E_{s1} = E_s = 200000.00$   
 $y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $f_{y2} = 299.3701$   
 $s_{u2} = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$   
 $s_{u2} = 0.4 * e_{s2\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{s2\_nominal} = 0.08$ ,  
 For calculation of  $e_{s2\_nominal}$  and  $y_2, sh_2, ft_2, f_{y2}$ , it is considered  
 characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.  
 $y_2, sh_2, ft_2, f_{y2}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{s2} = f_s = 299.3701$   
 with  $E_{s2} = E_s = 200000.00$   
 $y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $f_{yv} = 299.3701$   
 $s_{uv} = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.28304984$   
 $s_{uv} = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $e_{suv\_nominal} = 0.08$ ,  
 considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $e_{suv\_nominal}$  and  $y_v, sh_v, ft_v, f_{yv}$ , it is considered  
 characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{sv} = f_s = 299.3701$   
 with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.18776209$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08915322$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.16614919$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$   
 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  
 --->  
 $su (4.8) = 0.32281672$

$$\begin{aligned} \mu_u &= M/R_c(4.15) = 3.9843E+008 \\ u &= s_u(4.1) = 1.1848408E-005 \end{aligned}$$

Calculation of ratio  $l_b/l_d$

$$\begin{aligned} \text{Lap Length: } l_b/l_d &= 0.28304984 \\ l_b &= 300.00 \\ l_d &= 1059.884 \end{aligned}$$

Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$\begin{aligned} &= 1 \\ d_b &= 18.00 \\ \text{Mean strength value of all re-bars: } f_y &= 555.55 \\ f_c' &= 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)} \\ t &= 1.00 \\ s &= 0.80 \\ e &= 1.00 \\ c_b &= 25.00 \\ K_{tr} &= 2.61799 \\ A_{tr} &= \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796 \\ &\text{where } A_{tr_x}, A_{tr_y} \text{ are the sum of the area of all stirrup legs along X and Y local axis} \\ s &= 150.00 \\ n &= 16.00 \end{aligned}$$

Calculation of  $\mu_u$

$$\begin{aligned} \text{Calculation of ultimate curvature } u &\text{ according to 4.1, Biskinis/Fardis 2013:} \\ u &= 9.6917274E-006 \\ \mu_u &= 2.1970E+008 \end{aligned}$$

with full section properties:

$$\begin{aligned} b &= 600.00 \\ d &= 557.00 \\ d' &= 43.00 \\ v &= 0.00132912 \\ N &= 8883.864 \\ f_c &= 20.00 \\ c_o \text{ (5A.5, TBDY)} &= 0.002 \\ \text{Final value of } c_u: c_u^* &= \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353 \\ \text{The Shear\_factor is considered equal to 1 (pure moment strength)} \\ \text{From (5.4b), TBDY: } c_u &= 0.0144353 \\ v_e \text{ ((5.4c), TBDY)} &= a_s e * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805 \\ \text{where } f &= a_f * p_f * f_{fe} / f_{ce} \text{ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)} \end{aligned}$$

$$\begin{aligned} f_x &= 0.06888919 \\ \text{Expression ((15B.6), TBDY) is modified as } a_f &= 1 - (\text{Unconfined area}) / (\text{total area}) \\ a_f &= 0.24098246 \\ \text{with Unconfined area} &= ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333 \\ b_{\max} &= 600.00 \\ h_{\max} &= 600.00 \\ \text{From EC8 A.4.4.3(6), } p_f &= 2t_f / b_w = 0.008128 \\ b_w &= 250.00 \\ \text{effective stress from (A.35), } f_{f,e} &= 703.4155 \end{aligned}$$

$$\begin{aligned} f_y &= 0.06888919 \\ \text{Expression ((15B.6), TBDY) is modified as } a_f &= 1 - (\text{Unconfined area}) / (\text{total area}) \\ a_f &= 0.24098246 \\ \text{with Unconfined area} &= ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00 \\ b_{\max} &= 600.00 \\ h_{\max} &= 600.00 \\ \text{From EC8 A.4.4.3(6), } p_f &= 2t_f / b_w = 0.008128 \\ b_w &= 250.00 \\ \text{effective stress from (A.35), } f_{f,e} &= 703.4155 \end{aligned}$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$$fy_1 = 299.3701$$

$$su_1 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o / l_{o,min} = l_b / l_d = 0.28304984$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 299.3701$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00124738$$

$$sh_2 = 0.00431097$$

$$ft_2 = 359.2441$$

$$fy_2 = 299.3701$$

$$su_2 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o / l_{o,min} = l_b / l_{b,min} = 0.28304984$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,

For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{s2} = f_s = 299.3701$   
 with  $E_{s2} = E_s = 200000.00$   
 $y_v = 0.00124738$   
 $sh_v = 0.00431097$   
 $ft_v = 359.2441$   
 $fy_v = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{ou,min} = l_b/l_d = 0.28304984$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 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  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $f_{sv} = f_s = 299.3701$   
 with  $E_{sv} = E_s = 200000.00$   
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.03714718$   
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.0782342$   
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.06922883$

and confined core properties:

$b = 540.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.04362424$   
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09187529$   
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.08129972$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

---

$su (4.9) = 0.17212448$   
 $Mu = MRc (4.14) = 2.1970E+008$   
 $u = su (4.1) = 9.6917274E-006$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars:  $f_y = 555.55$

$f'_c = 20.00$ , but  $f'_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1,  $Vr1 = 424229.688$

$Vr1 = VCol$  ((10.3), ASCE 41-17) =  $knl * VColO$

$VColO = 424229.688$

$knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$fc' = 20.00$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 47.24078$

$Vu = 0.00016213$

$d = 0.8 * h = 480.00$

$Nu = 8883.864$

$Ag = 150000.00$

From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 316483.206$

where:

$Vs1 = 223399.91$  is calculated for section web, with:

$d = 480.00$

$Av = 157079.633$

$fy = 444.44$

$s = 150.00$

$Vs1$  is multiplied by  $Col1 = 1.00$

$s/d = 0.3125$

$Vs2 = 93083.296$  is calculated for section flange, with:

$d = 200.00$

$Av = 157079.633$

$fy = 444.44$

$s = 150.00$

$Vs2$  is multiplied by  $Col2 = 1.00$

$s/d = 0.75$

$Vf$  ((11-3)-(11.4), ACI 440) =  $293495.545$

$f = 0.95$ , for fully-wrapped sections

$wf/sf = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $Vf(a, \dots)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $a = b1 + 90^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, a1)|, |Vf(-45, a1)|)$ , with:

total thickness per orientation,  $tf1 = NL * t / \text{NoDir} = 1.016$

$dfv = d$  (figure 11.2, ACI 440) =  $557.00$

$ffe$  ((11-5), ACI 440) =  $259.312$

$Ef = 64828.00$

$fe = 0.004$ , from (11.6a), ACI 440

with  $fu = 0.01$

From (11-11), ACI 440:  $Vs + Vf \leq 356502.845$

$bw = 250.00$

Calculation of Shear Strength at edge 2,  $Vr2 = 424229.688$

$Vr2 = VCol$  ((10.3), ASCE 41-17) =  $knl * VColO$

$VColO = 424229.688$

$knl = 1$  (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$fc' = 20.00$ , but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 47.24081$

$Vu = 0.00016213$

$d = 0.8 * h = 480.00$

$Nu = 8883.864$

$Ag = 150000.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 223399.91$  is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.3125$

$V_{s2} = 93083.296$  is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.75$

$V_f$  ((11-3)-(11.4), ACI 440) = 293495.545

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot_a)\sin\alpha$  which is more a generalised expression, where  $\alpha$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\alpha)$ , is implemented for every different fiber orientation  $\alpha_i$ , as well as for 2 crack directions,  $\alpha = 45^\circ$  and  $\alpha = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\alpha = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$ , with:

total thickness per orientation,  $t_{f1} = NL*t/NoDir = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 557.00

$f_{fe}$  ((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:  $V_s + V_f \leq 356502.845$

$b_w = 250.00$

-----  
End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 3

-----  
Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rclcs

Constant Properties

-----  
Knowledge Factor,  $\gamma = 0.77$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$

Concrete Elasticity,  $E_c = 21019.039$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength,  $f_s = 1.25*f_{sm} = 555.55$

#####

Max Height,  $H_{max} = 600.00$

Min Height,  $H_{min} = 250.00$

Max Width,  $W_{max} = 600.00$

Min Width,  $W_{min} = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length,  $L = 3000.00$

Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Lap Length  $l_o = 300.00$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $b_i = 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = 0.00016213$   
EDGE -B-  
Shear Force,  $V_b = -0.00016213$   
BOTH EDGES  
Axial Force,  $F = -8883.864$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 4121.77$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 1746.726$   
-Compression:  $A_{st,com} = 829.3805$   
-Middle:  $A_{st,mid} = 1545.664$

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.62612363$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$   
with

$M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 3.9843E+008$

$Mu_{1+} = 3.9843E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.1970E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 3.9843E+008$

$Mu_{2+} = 3.9843E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$Mu_{2-} = 2.1970E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of  $Mu_{1+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.1848408E-005$

$M_u = 3.9843E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length

equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$sh1 = 0.00431097$   
 $ft1 = 359.2441$   
 $fy1 = 299.3701$   
 $su1 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/l_d = 0.28304984$   
 $su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$   
 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  $Min(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs1 = fs = 299.3701$   
 with  $Es1 = Es = 200000.00$   
 $y2 = 0.00124738$   
 $sh2 = 0.00431097$   
 $ft2 = 359.2441$   
 $fy2 = 299.3701$   
 $su2 = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/l_{b,min} = 0.28304984$   
 $su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$   
 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  $Min(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fs2 = fs = 299.3701$   
 with  $Es2 = Es = 200000.00$   
 $yv = 0.00124738$   
 $shv = 0.00431097$   
 $ftv = 359.2441$   
 $fyv = 299.3701$   
 $suv = 0.00446911$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/l_d = 0.28304984$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv$ ,  $shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1$ ,  $sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.  
 with  $fsv = fs = 299.3701$   
 with  $Esv = Es = 200000.00$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.18776209$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.08915322$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.16614919$   
 and confined core properties:  
 $b = 190.00$   
 $d = 527.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 21.96205$   
 $cc (5A.5, TBDY) = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.26111925$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.12398468$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.23106236$   
 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

--->

$$su(4.8) = 0.32281672$$

$$Mu = MRc(4.15) = 3.9843E+008$$

$$u = su(4.1) = 1.1848408E-005$$

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Lap Length:  $lb/l_d = 0.28304984$

$$lb = 300.00$$

$$l_d = 1059.884$$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars:  $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = 150.00$$

$$n = 16.00$$

-----  
Calculation of Mu1-

-----  
Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 9.6917274E-006$$

$$Mu = 2.1970E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, \text{ TBDY}) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$\text{we ((5.4c), TBDY) } = a_s e^* \text{ sh, min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 57233.333$$

$$b_{\text{max}} = 600.00$$

$$h_{\text{max}} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

-----  
 $f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as  $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 0.00$$

$$b_{\text{max}} = 600.00$$

$$h_{\text{max}} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

bw = 250.00  
effective stress from (A.35),  $f_{f,e} = 703.4155$

R = 40.00  
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$   
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.

$A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.  
 $A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $b_i^2/6$  as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for  $p_{sh,min}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along Y) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along X) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

s = 150.00  
 $f_{ywe} = 555.55$   
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$   
c = confinement factor = 1.0981

$y_1 = 0.00124738$   
 $sh_1 = 0.00431097$   
 $ft_1 = 359.2441$   
 $fy_1 = 299.3701$   
 $su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $fs_1 = fs = 299.3701$

with  $E_{s1} = E_s = 200000.00$

$y_2 = 0.00124738$   
 $sh_2 = 0.00431097$   
 $ft_2 = 359.2441$   
 $fy_2 = 299.3701$   
 $su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered

characteristic value  $f_{s2} = f_s/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{s2} = f_s = 299.3701$

with  $E_{s2} = E_s = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$s_{uv} = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/d = 0.28304984$

$s_{uv} = 0.4 \cdot e_{suv,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $e_{suv,nominal} = 0.08$ ,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , 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  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$ , from 10.3.5, ASCE41-17.

with  $f_{sv} = f_s = 299.3701$

with  $E_{sv} = E_s = 200000.00$

1 =  $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03714718$

2 =  $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0782342$

v =  $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06922883$

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

f<sub>cc</sub> (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

1 =  $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04362424$

2 =  $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09187529$

v =  $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08129972$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

---

$\mu_u$  (4.9) = 0.17212448

$\mu_u = M/R_c$  (4.14) = 2.1970E+008

u =  $\mu_u$  (4.1) = 9.6917274E-006

-----  
Calculation of ratio  $l_b/d$

Lap Length:  $l_b/d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

Calculation of  $l_{b,min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 18.00$

Mean strength value of all re-bars:  $f_y = 555.55$

$f'_c = 20.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

s = 150.00

n = 16.00

-----  
-----  
-----  
Calculation of  $\mu_{u2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.1848408E-005$$

$$\mu_u = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.0144353$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.0144353$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = \alpha s_e * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where  $f = \alpha f_p * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 57233.333$$

$$b_{\text{max}} = 600.00$$

$$h_{\text{max}} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 0.00$$

$$b_{\text{max}} = 600.00$$

$$h_{\text{max}} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,max}} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{\text{conf,max}}$  by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$  is the unconfined core area which is equal to  $b_i^2 / 6$  as defined at (A.2).

$$p_{sh,\text{min}} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for  $p_{sh,\text{min}}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$\text{psh,y ((5.4d), TBDY)} = \text{Lstir} \cdot \text{Astir} / (\text{Asec} \cdot \text{s}) = 0.00321875$$

$$\text{Lstir (Length of stirrups along X)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$\text{s} = 150.00$$

$$\text{fywe} = 555.55$$

$$\text{fce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: cc} = 0.00298102$$

$$\text{c} = \text{confinement factor} = 1.0981$$

$$\text{y1} = 0.00124738$$

$$\text{sh1} = 0.00431097$$

$$\text{ft1} = 359.2441$$

$$\text{fy1} = 299.3701$$

$$\text{su1} = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$\text{lo/lou,min} = \text{lb/l d} = 0.28304984$$

$$\text{su1} = 0.4 \cdot \text{esu1\_nominal ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (\text{lb/l d})^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with fs1} = \text{fs} = 299.3701$$

$$\text{with Es1} = \text{Es} = 200000.00$$

$$\text{y2} = 0.00124738$$

$$\text{sh2} = 0.00431097$$

$$\text{ft2} = 359.2441$$

$$\text{fy2} = 299.3701$$

$$\text{su2} = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$\text{lo/lou,min} = \text{lb/l b,min} = 0.28304984$$

$$\text{su2} = 0.4 \cdot \text{esu2\_nominal ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (\text{lb/l d})^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with fs2} = \text{fs} = 299.3701$$

$$\text{with Es2} = \text{Es} = 200000.00$$

$$\text{yv} = 0.00124738$$

$$\text{shv} = 0.00431097$$

$$\text{ftv} = 359.2441$$

$$\text{fyv} = 299.3701$$

$$\text{suv} = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$\text{lo/lou,min} = \text{lb/l d} = 0.28304984$$

$$\text{suv} = 0.4 \cdot \text{esuv\_nominal ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (\text{lb/l d})^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with fsv} = \text{fs} = 299.3701$$

$$\text{with Esv} = \text{Es} = 200000.00$$

$$1 = \text{Asl,ten} / (\text{b} \cdot \text{d}) \cdot (\text{fs1} / \text{fc}) = 0.18776209$$

$$2 = \text{Asl,com} / (\text{b} \cdot \text{d}) \cdot (\text{fs2} / \text{fc}) = 0.08915322$$

$$\text{v} = \text{Asl,mid} / (\text{b} \cdot \text{d}) \cdot (\text{fsv} / \text{fc}) = 0.16614919$$

and confined core properties:

$$\text{b} = 190.00$$

$$\text{d} = 527.00$$

$$\text{d}' = 13.00$$

$$\text{fcc (5A.2, TBDY)} = 21.96205$$

$$cc \text{ (5A.5, TBDY)} = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236$$

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

$$su \text{ (4.8)} = 0.32281672$$

$$Mu = MRc \text{ (4.15)} = 3.9843E+008$$

$$u = su \text{ (4.1)} = 1.1848408E-005$$

-----  
Calculation of ratio  $lb/ld$

$$\text{Lap Length: } lb/ld = 0.28304984$$

$$lb = 300.00$$

$$ld = 1059.884$$

Calculation of  $lb,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

$$db = 18.00$$

Mean strength value of all re-bars:  $fy = 555.55$

$$fc' = 20.00, \text{ but } fc^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 2.61799$$

$$Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$$

where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = 150.00$$

$$n = 16.00$$

-----  
Calculation of  $Mu2-$

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 9.6917274E-006$$

$$Mu = 2.1970E+008$$

-----  
with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$fc = 20.00$$

$$co \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.0144353$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.0144353$$

$$\text{we ((5.4c), TBDY) } = ase * sh,min * fywe / fce + \text{Min}(fx, fy) = 0.07473805$$

where  $f = af * pf * ffe / fce$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.06888919$$

Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$$af = 0.24098246$$

$$\text{with Unconfined area} = ((bmax - 2R)^2 + (hmax - 2R)^2) / 3 = 57233.333$$

$$bmax = 600.00$$

$$hmax = 600.00$$

From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.008128$   
 $bw = 250.00$   
effective stress from (A.35),  $ff,e = 703.4155$

$fy = 0.06888919$   
Expression ((15B.6), TBDY) is modified as  $af = 1 - (\text{Unconfined area})/(\text{total area})$   
 $af = 0.24098246$   
with Unconfined area =  $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$   
 $b_{max} = 600.00$   
 $h_{max} = 600.00$   
From EC8 A4.4.3(6),  $pf = 2tf/bw = 0.008128$   
 $bw = 250.00$   
effective stress from (A.35),  $ff,e = 703.4155$

$R = 40.00$   
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
 $fu,f = 1055.00$   
 $Ef = 64828.00$   
 $u,f = 0.015$   
 $ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.21805635$   
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.  
 $A_{conf,max} = 169100.00$  is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.  
 $A_{conf,min} = 98400.00$  is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area  $A_{conf,max}$  by a length equal to half the clear spacing between hoops.  
 $A_{noConf} = 105733.333$  is the unconfined core area which is equal to  $bi^2/6$  as defined at (A.2).  
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$   
Expression ((5.4d), TBDY) for  $psh,min$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x$  ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along Y) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

$psh,y$  ((5.4d), TBDY) =  $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$   
 $L_{stir}$  (Length of stirrups along X) = 1460.00  
 $A_{stir}$  (stirrups area) = 78.53982  
 $A_{sec}$  (section area) = 237500.00

$s = 150.00$   
 $fywe = 555.55$   
 $fce = 20.00$   
From ((5.A5), TBDY), TBDY:  $cc = 0.00298102$   
 $c = \text{confinement factor} = 1.0981$   
 $y1 = 0.00124738$   
 $sh1 = 0.00431097$   
 $ft1 = 359.2441$   
 $fy1 = 299.3701$   
 $su1 = 0.00446911$   
using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$  and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  $Shear\_factor = 1.00$   
 $lo/lou,min = lb/d = 0.28304984$   
 $su1 = 0.4*esu1\_nominal$  ((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  $\text{Min}(1, 1.25*(lb/d)^{2/3})$ , from 10.3.5, ASCE41-17.  
with  $fs1 = fs = 299.3701$   
with  $Es1 = Es = 200000.00$   
 $y2 = 0.00124738$

$$sh_2 = 0.00431097$$

$$ft_2 = 359.2441$$

$$fy_2 = 299.3701$$

$$su_2 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lo_{min} = lb/lb_{min} = 0.28304984$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,

For calculation of  $esu_{2,nominal}$  and  $y_2$ ,  $sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 299.3701$$

$$\text{with } Es_2 = Es = 200000.00$$

$$yv = 0.00124738$$

$$shv = 0.00431097$$

$$ftv = 359.2441$$

$$fyv = 299.3701$$

$$suv = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lo_{min} = lb/ld = 0.28304984$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv_{nominal}$  and  $yv$ ,  $shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 299.3701$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.03714718$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.0782342$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.06922883$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 21.96205$$

$$cc (5A.5, TBDY) = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.04362424$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.09187529$$

$$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08129972$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs_y2$  - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.17212448$$

$$Mu = MRc (4.14) = 2.1970E+008$$

$$u = su (4.1) = 9.6917274E-006$$

Calculation of ratio  $lb/ld$

$$\text{Lap Length: } lb/ld = 0.28304984$$

$$lb = 300.00$$

$$ld = 1059.884$$

Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars:  $fy = 555.55$

$$fc' = 20.00, \text{ but } fc'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.61799$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$   
 where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = 150.00$   
 $n = 16.00$

-----  
 Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1,  $V_{r1} = 424229.688$   
 $V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$   
 $V_{Col0} = 424229.688$   
 $k_{nl} = 1$  (zero step-static loading)

NOTE: In expression (10-3) ' $V_s$ ' is replaced by ' $V_s + f * V_f$ '  
 where  $V_f$  is the contribution of FRPs (11.3), ACI 440).

$f_c' = 20.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 4.00$   
 $\mu_u = 47.23669$   
 $\nu_u = 0.00016213$   
 $d = 0.8 * h = 480.00$   
 $N_u = 8883.864$   
 $A_g = 150000.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 93083.296$  is calculated for section web, with:

$d = 200.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$

$V_{s1}$  is multiplied by  $Col1 = 1.00$

$s/d = 0.75$

$V_{s2} = 223399.91$  is calculated for section flange, with:

$d = 480.00$   
 $A_v = 157079.633$   
 $f_y = 444.44$   
 $s = 150.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.3125$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$

$f = 0.95$ , for fully-wrapped sections

$w_f/s_f = 1$  (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression, where  $a$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:

total thickness per orientation,  $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 557.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$ , from (11.6a), ACI 440

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 356502.845$

$b_w = 250.00$

-----  
 Calculation of Shear Strength at edge 2,  $V_{r2} = 424229.688$

$V_{r2} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$   
 $V_{Col0} = 424229.688$

knl = 1 (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f\*Vf'  
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

fc' = 20.00, but  $fc^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 47.23667

Vu = 0.00016213

d = 0.8\*h = 480.00

Nu = 8883.864

Ag = 150000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 316483.206

where:

Vs1 = 93083.296 is calculated for section web, with:

d = 200.00

Av = 157079.633

fy = 444.44

s = 150.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.75

Vs2 = 223399.91 is calculated for section flange, with:

d = 480.00

Av = 157079.633

fy = 444.44

s = 150.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.3125

Vf ((11-3)-(11.4), ACI 440) = 293495.545

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
where  $\alpha$  is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(  $\alpha$  ), is implemented for every different fiber orientation ai,  
as well as for 2 crack directions,  $\alpha = 45^\circ$  and  $\alpha = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\alpha = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45,  $\alpha$ )|, |Vf(-45,  $\alpha$ )|), with:

total thickness per orientation, tf1 = NL\*t/NoDir = 1.016

dfv = d (figure 11.2, ACI 440) = 557.00

ffe ((11-5), ACI 440) = 259.312

Ef = 64828.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.01

From (11-11), ACI 440: Vs + Vf <= 356502.845

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1  
At local axis: 3

Integration Section: (b)

Section Type: rldcs

Constant Properties

Knowledge Factor,  $\gamma = 0.77$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00

Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity,  $E_c = 21019.039$   
 Steel Elasticity,  $E_s = 200000.00$   
 Max Height,  $H_{max} = 600.00$   
 Min Height,  $H_{min} = 250.00$   
 Max Width,  $W_{max} = 600.00$   
 Min Width,  $W_{min} = 250.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Lap Length  $l_b = 300.00$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $e_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i = 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

-----  
 Stepwise Properties

-----  
 Bending Moment,  $M = 136240.323$   
 Shear Force,  $V_2 = 3536.316$   
 Shear Force,  $V_3 = -123.1168$   
 Axial Force,  $F = -9530.256$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $A_{st} = 0.00$   
 -Compression:  $A_{sc} = 4121.77$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $A_{st,ten} = 1746.726$   
 -Compression:  $A_{st,com} = 829.3805$   
 -Middle:  $A_{st,mid} = 1545.664$   
 Mean Diameter of Tension Reinforcement,  $Db_L = 17.71429$

-----  
 Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = \dots$   $u = 0.03287888$   
 $u = y + p = 0.04269984$

-----  
 - Calculation of  $y$  -

-----  
 $y = (M_y * L_s / 3) / E_{eff} = 0.00069984$  ((4.29), Biskinis Phd)  
 $M_y = 2.9338E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 4.1921E+013$   
 $factor = 0.30$   
 $A_g = 237500.00$   
 $f_c' = 20.00$   
 $N = 9530.256$   
 $E_c * I_g = 1.3974E+014$

-----  
 Calculation of Yielding Moment  $M_y$

-----  
 Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 4.0516275\text{E-}006$   
 with  $((10.1), \text{ASCE } 41-17) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/l_d)^{2/3}) = 277.9106$   
 $d = 557.00$   
 $y = 0.38426988$   
 $A = 0.02984605$   
 $B = 0.01922829$   
 with  $pt = 0.01254381$   
 $pc = 0.00595605$   
 $pv = 0.01109992$   
 $N = 9530.256$   
 $b = 250.00$   
 $" = 0.07719928$   
 $y_{\text{comp}} = 8.1950430\text{E-}006$   
 with  $fc^* (12.3, (\text{ACI } 440)) = 20.42407$   
 $fc = 20.00$   
 $fl = 0.62098351$   
 $b = b_{\text{max}} = 600.00$   
 $h = h_{\text{max}} = 600.00$   
 $Ag = 237500.00$   
 $g = pt + pc + pv = 0.02959978$   
 $rc = 40.00$   
 $Ae/Ac = 0.21783041$   
 Effective FRP thickness,  $tf = NL \cdot t \cdot \text{Cos}(b1) = 1.016$   
 effective strain from (12.5) and (12.12),  $efe = 0.004$   
 $fu = 0.01$   
 $Ef = 64828.00$   
 $Ec = 21019.039$   
 $y = 0.38317351$   
 $A = 0.02940413$   
 $B = 0.01898202$   
 with  $Es = 200000.00$

-----  
 -----  
 Calculation of ratio  $l_b/l_d$   
 -----

Lap Length:  $l_d/l_{d,\text{min}} = 0.3538123$   
 $l_b = 300.00$   
 $l_d = 847.9072$   
 Calculation of  $l$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 18.00$   
 Mean strength value of all re-bars:  $f_y = 444.44$   
 $fc' = 20.00$ , but  $fc^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.61799$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$   
 where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = 150.00$   
 $n = 16.00$

-----  
 -----  
 - Calculation of  $p$  -  
 -----

From table 10-8:  $p = 0.042$   
 with:  
 - Columns not controlled by inadequate development or splicing along the clear height because  $l_b/l_d \geq 1$   
 shear control ratio  $V_y E / V_{CoIOE} = 0.62612363$   
 $d = 557.00$   
 $s = 0.00$   
 $t = Av / (bw \cdot s) + 2 \cdot tf / bw \cdot (ffe / fs) = Av \cdot L_{\text{stir}} / (Ag \cdot s) + 2 \cdot tf / bw \cdot (ffe / fs) = 0.00$   
 $Av = 78.53982$ , is the area of every stirrup  
 $L_{\text{stir}} = 1460.00$ , is the total Length of all stirrups parallel to loading (shear) direction

The term  $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$  is implemented to account for FRP contribution where  $f = 2 \cdot t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength. All these variables have already been given in Shear control ratio calculation.

$$N_{UD} = 9530.256$$

$$A_g = 237500.00$$

$$f_{cE} = 20.00$$

$$f_{yE} = f_{yI} = 0.00$$

$$p_l = \text{Area\_Tot\_Long\_Rein} / (b \cdot d) = 0.02959978$$

$$b = 250.00$$

$$d = 557.00$$

$$f_{cE} = 20.00$$

-----  
End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

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