

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

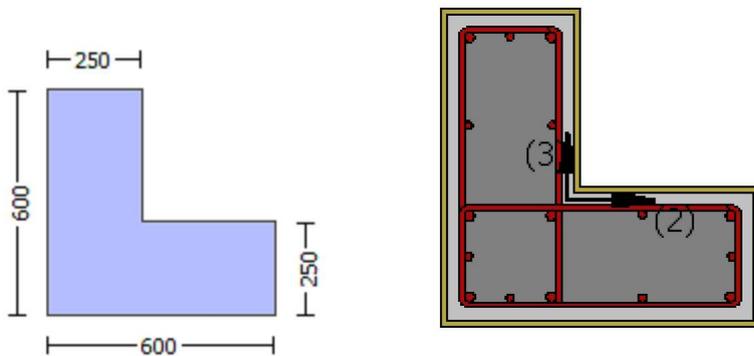
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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, $\gamma = 1.00$

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 Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ 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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

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, $M_a = -8.5294E+006$

Shear Force, $V_a = -2806.138$

EDGE -B-

Bending Moment, $M_b = 108099.704$

Shear Force, $V_b = 2806.138$

BOTH EDGES

Axial Force, $F = -9396.789$

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, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 379585.591$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 379585.591$

$V_{CoI} = 379585.591$

$k_n = 1.00$

displacement_ductility_demand = 0.01224661

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).

= 1 (normal-weight concrete)

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

$M/Vd = 4.00$

$\mu_u = 8.5294E+006$
 $V_u = 2806.138$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9396.789$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 66138.793$
 where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.90$
 $V_{s2} = 66138.793$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
 V_{s2} is multiplied by $Col2 = 0.83333333$
 $s/d = 0.79166667$
 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 θ 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 α_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 δ / y

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

From analysis, chord rotation $\theta = 8.3496036E-005$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00681789$ ((4.29), Biskinis Phd))
 $M_y = 2.8210E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3039.54
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$
 $\text{factor} = 0.30$
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9396.789$
 $E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.8954822E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 267.1762$
 $d = 557.00$

$y = 0.38432516$
 $A = 0.02985235$
 $B = 0.0192346$
 with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9396.789$
 $b = 250.00$
 $" = 0.07719928$
 $y_{comp} = 8.1953653E-006$
 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, $tf = NL*t*\cos(\theta) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 21019.039$
 $y = 0.38315844$
 $A = 0.02940687$
 $B = 0.01898202$
 with $Es = 200000.00$

 Calculation of ratio l_b/l_d

 Lap Length: $l_d/l_{d,min} = 0.33351241$

$l_b = 300.00$

$l_d = 899.5167$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.03342$

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

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

$s = 380.00$

$n = 16.00$

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

At local axis: 2

Integration Section: (a)

Calculation No. 2

column C1, Floor 1

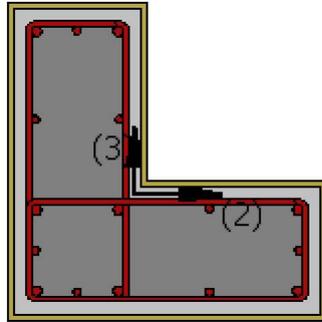
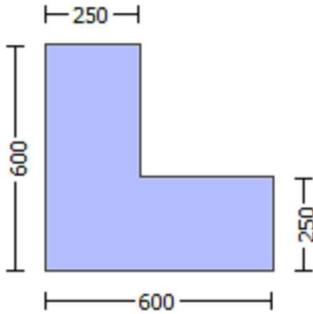
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

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, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, 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 , $V_e/V_r = 0.60501747$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$
with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.8119\text{E}+008$
 $\mu_{1+} = 3.8119\text{E}+008$, 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
 $\mu_{1-} = 2.0589\text{E}+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.8119\text{E}+008$
 $\mu_{2+} = 3.8119\text{E}+008$, 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
 $\mu_{2-} = 2.0589\text{E}+008$, 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 μ_{1+}

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

$$\mu = 1.0933130\text{E}-005$$

$$M_u = 3.8119\text{E}+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00318999$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_c: \mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.014005$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.00781147$

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

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

$A_{conf,min} = 3525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

c = confinement factor = 1.0981

$y1 = 0.0011992$

$sh1 = 0.00414446$

$ft1 = 345.3682$

$fy1 = 287.8069$

$su1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/ld = 0.26680993$

$su1 = 0.4*esu1_{nominal}$ ((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 $f_{s1} = f_s = 287.8069$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.26680993$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{s2} = f_s = 287.8069$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $fy_v = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.26680993$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sv} = f_s = 287.8069$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.18050973$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08570966$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.15973163$

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.25103346$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11919574$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.22213752$

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

--->
 $su (4.8) = 0.31943706$
 $Mu = MRc (4.15) = 3.8119E+008$
 $u = su (4.1) = 1.0933130E-005$

 Calculation of ratio l_b/l_d

 Lap Length: $l_b/l_d = 0.26680993$
 $l_b = 300.00$
 $l_d = 1124.396$

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 = 1.03342

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

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

s = 380.00

n = 16.00

Calculation of μ_1 -

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

$\mu = 9.0418593E-006$

$\mu_1 = 2.0589E+008$

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_s) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.014005$

where μ_s ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{f,1} = 0.015$

$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$

The definitions of A_{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.

$A_{conf,min} = 3525.00$ is 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).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00127056$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y_1 = 0.0011992$

$sh_1 = 0.00414446$

$ft_1 = 345.3682$

$fy_1 = 287.8069$

$su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{min} = lb/l_d = 0.26680993$

$su_1 = 0.4 * esu_{1_nominal}$ ((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 $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$

$sh_2 = 0.00414446$

$ft_2 = 345.3682$

$fy_2 = 287.8069$

$su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{min} = lb/l_{b,min} = 0.26680993$

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

with $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$su_v = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{min} = lb/l_d = 0.26680993$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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 $fsv = fs = 287.8069$

with $Esv = Es = 200000.00$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.03571236$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.07521239$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.06655485$$

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.04193924$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.08832659$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.0781595$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$$su (4.9) = 0.17708486$$

$$Mu = MRc (4.14) = 2.0589E+008$$

$$u = su (4.1) = 9.0418593E-006$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$

$$lb = 300.00$$

$$ld = 1124.396$$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 1.03342$$

$$Atr = Min(Atr_x, Atr_y) = 157.0796$$

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of $Mu2+$

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

$$u = 1.0933130E-005$$

$$Mu = 3.8119E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0011992$$

$$sh_1 = 0.00414446$$

$$ft_1 = 345.3682$$

$f_{y1} = 287.8069$
 $s_{u1} = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.26680993$
 $s_{u1} = 0.4 * e_{su1,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{s1} = f_s = 287.8069$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $f_{y2} = 287.8069$
 $s_{u2} = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.26680993$
 $s_{u2} = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{s2} = f_s = 287.8069$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $f_{yv} = 287.8069$
 $s_{uv} = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.26680993$
 $s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sv} = f_s = 287.8069$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.18050973$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08570966$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.15973163$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.25103346$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11919574$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.22213752$
 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
 --->
 $s_u (4.8) = 0.31943706$

$$\begin{aligned} \mu_u &= M/R_c(4.15) = 3.8119E+008 \\ u &= s_u(4.1) = 1.0933130E-005 \end{aligned}$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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: $f_y = 555.55$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of μ_u

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

$$u = 9.0418593E-006$$

$$\mu_u = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e((5.4c), \text{ TBDY}) = a_{se} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

c = confinement factor = 1.0981

$y_1 = 0.0011992$

$sh_1 = 0.00414446$

$ft_1 = 345.3682$

$fy_1 = 287.8069$

$su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.26680993$

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

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 $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$

$sh_2 = 0.00414446$

$ft_2 = 345.3682$

$fy_2 = 287.8069$

$su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.26680993$

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

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 $f_{s2} = f_s = 287.8069$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $fy_v = 287.8069$
 $su_v = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.26680993$
 $su_v = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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 $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 287.8069$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.03571236$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07521239$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.06655485$

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.04193924$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.08832659$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.0781595$

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

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17708486$
 $Mu = MRc (4.14) = 2.0589E+008$
 $u = su (4.1) = 9.0418593E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$l_b = 300.00$

$l_d = 1124.396$

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)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.03342$
 $A_{tr} = Min(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis
 $s = 380.00$
 $n = 16.00$

Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 420034.424$

Calculation of Shear Strength at edge 1, $Vr1 = 420034.424$

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

$VColO = 420034.424$

$knl = 1$ (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: $Vs = Vs1 + Vs2 = 73486.813$

where:

$Vs1 = 73486.813$ is calculated for section web, with:

$d = 480.00$

$Av = 157079.633$

$fy = 444.44$

$s = 380.00$

$Vs1$ is multiplied by $Col1 = 0.83333333$

$s/d = 0.79166667$

$Vs2 = 0.00$ is calculated for section flange, with:

$d = 200.00$

$Av = 157079.633$

$fy = 444.44$

$s = 380.00$

$Vs2$ is multiplied by $Col2 = 0.00$

$s/d = 1.90$

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 θ is the angle of the crack direction (see KANEPE).

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

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

$Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, 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, $Vr2 = 420034.424$

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

$VColO = 420034.424$

$knl = 1$ (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: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.83333333$

$s/d = 0.79166667$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.90$

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 α 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 α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

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

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

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

$d_{fv} = d$ (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, $\phi = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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, $L = 3000.00$

Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
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, $V_e/V_r = 0.60501747$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$
with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.8119E+008$

$Mu_{1+} = 3.8119E+008$, 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

$Mu_{1-} = 2.0589E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.8119E+008$

$Mu_{2+} = 3.8119E+008$, 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

$Mu_{2-} = 2.0589E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.0933130E-005$

$M_u = 3.8119E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$$

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

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

$A_{conf,min} = 3525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0011992$$

$sh1 = 0.00414446$
 $ft1 = 345.3682$
 $fy1 = 287.8069$
 $su1 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.26680993$
 $su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$
 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 $fs1 = fs = 287.8069$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0011992$
 $sh2 = 0.00414446$
 $ft2 = 345.3682$
 $fy2 = 287.8069$
 $su2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/lb,min = 0.26680993$
 $su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$
 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 $fs2 = fs = 287.8069$
 with $Es2 = Es = 200000.00$
 $yv = 0.0011992$
 $shv = 0.00414446$
 $ftv = 345.3682$
 $fyv = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.26680993$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 287.8069$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.18050973$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.08570966$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.15973163$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.25103346$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.11919574$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.22213752$
 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

--->

$$s_u(4.8) = 0.31943706$$

$$M_u = M_{Rc}(4.15) = 3.8119E+008$$

$$u = s_u(4.1) = 1.0933130E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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: $f_y = 555.55$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of μ_1 -

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

$$u = 9.0418593E-006$$

$$M_u = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } c_u = 0.014005$$

$$\text{we ((5.4c), TB DY) } = a_s e^* \text{ sh, min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

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

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

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$
The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

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

$A_{conf,min} = 3525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$
 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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

s = 380.00
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

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

$y_1 = 0.0011992$
 $sh_1 = 0.00414446$
 $ft_1 = 345.3682$
 $fy_1 = 287.8069$
 $su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.26680993$

$su_1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

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

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

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

with $fs_1 = fs = 287.8069$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.26680993$

$su_2 = 0.4 * esu2_{nominal}$ ((5.5), TBDY) = 0.032

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

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

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

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s2} = f_s = 287.8069$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$f_{y_v} = 287.8069$

$s_{u_v} = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/d = 0.26680993$

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

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

considering characteristic value $f_{s_{y_v}} = f_{s_v}/1.2$, from table 5.1, TBDY

For calculation of $e_{s_{u_v,nominal}}$ and y_v, sh_v, ft_v, f_{y_v} , it is considered
characteristic value $f_{s_{y_v}} = f_{s_v}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s_v} = f_s = 287.8069$

with $E_{s_v} = E_s = 200000.00$

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03571236$

2 = $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07521239$

v = $A_{s1,mid}/(b \cdot d) \cdot (f_{s_v}/f_c) = 0.06655485$

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 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04193924$

2 = $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08832659$

v = $A_{s1,mid}/(b \cdot d) \cdot (f_{s_v}/f_c) = 0.0781595$

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) = 0.17708486

$\mu_u = M_{Rc}$ (4.14) = 2.0589E+008

u = s_u (4.1) = 9.0418593E-006

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.26680993$

$l_b = 300.00$

$l_d = 1124.396$

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

$K_{tr} = 1.03342$

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

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

s = 380.00

n = 16.00

Calculation of μ_{u2+}

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

$$\mu = 1.0933130E-005$$

$$\mu_u = 3.8119E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.014005$$

$$\mu_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$f_y = 0.06888919$$

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

$$\alpha_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$$

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

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

$A_{conf,min} = 3525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

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

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

$$y1 = 0.0011992$$

$$sh1 = 0.00414446$$

$$ft1 = 345.3682$$

$$fy1 = 287.8069$$

$$su1 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/d = 0.26680993$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs1 = fs = 287.8069$$

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

$$y2 = 0.0011992$$

$$sh2 = 0.00414446$$

$$ft2 = 345.3682$$

$$fy2 = 287.8069$$

$$su2 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.26680993$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs2 = fs = 287.8069$$

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

$$yv = 0.0011992$$

$$shv = 0.00414446$$

$$ftv = 345.3682$$

$$fyv = 287.8069$$

$$suv = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/d = 0.26680993$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = fs = 287.8069$$

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.18050973$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.08570966$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.15973163$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

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

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

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

$$1 = \text{Asl,ten}/(b*d)*(fs1/fc) = 0.25103346$$

$$2 = \text{Asl,com}/(b*d)*(fs2/fc) = 0.11919574$$

$$v = \text{Asl,mid}/(b*d)*(fsv/fc) = 0.22213752$$

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

---->
 $su \text{ (4.8)} = 0.31943706$

$$Mu = MRc \text{ (4.15)} = 3.8119E+008$$

$$u = su \text{ (4.1)} = 1.0933130E-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$

$$lb = 300.00$$

$$ld = 1124.396$$

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: $f_y = 555.55$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of Mu_2 -

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

$$u = 9.0418593E-006$$

$$Mu = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$fc = 20.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.014005$$

$$\text{we ((5.4c), TBDY) } = ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.0689719$$

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 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, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $fu,f = 1055.00$
 $Ef = 64828.00$
 $u,f = 0.015$
 $ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.00781147$
The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.
 $A_{conf,min} = 3525.00$ is 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 $b^2/6$ as defined at (A.2).
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00127056$
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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
 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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

 $s = 380.00$
 $fywe = 555.55$
 $fce = 20.00$
From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $y1 = 0.0011992$
 $sh1 = 0.00414446$
 $ft1 = 345.3682$
 $fy1 = 287.8069$
 $su1 = 0.00414446$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.26680993$
 $su1 = 0.4*esu1_nominal$ ((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 $fs1 = fs = 287.8069$
with $Es1 = Es = 200000.00$
 $y2 = 0.0011992$

$sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 0.26680993$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = fs = 287.8069$
 with $Es_2 = Es = 200000.00$
 $yv = 0.0011992$
 $shv = 0.00414446$
 $ftv = 345.3682$
 $fyv = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 0.26680993$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 287.8069$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.03571236$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.07521239$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.06655485$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.04193924$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.08832659$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.0781595$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs_y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17708486$
 $Mu = MRc (4.14) = 2.0589E+008$
 $u = su (4.1) = 9.0418593E-006$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$
 $lb = 300.00$
 $ld = 1124.396$
 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 = 1.03342
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 local axis
s = 380.00
n = 16.00

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 420034.424$

Calculation of Shear Strength at edge 1, $V_{r1} = 420034.424$
 $V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$
 $V_{Col0} = 420034.424$
 $k_{nl} = 1$ (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)
 $M/Vd = 4.00$
 $\mu_u = 47.23669$
 $\nu_u = 0.00016213$
 $d = 0.8 * h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

V_{s1} is multiplied by $\text{Col1} = 0.00$

$s/d = 1.90$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

V_{s2} is multiplied by $\text{Col2} = 0.83333333$

$s/d = 0.79166667$

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

$f = 0.95$, 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 α 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: $\alpha = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$ (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, $V_{r2} = 420034.424$

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

$V_{Col0} = 420034.424$

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 = 73486.813

where:

Vs1 = 0.00 is calculated for section web, with:

d = 200.00

Av = 157079.633

fy = 444.44

s = 380.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.90

Vs2 = 73486.813 is calculated for section flange, with:

d = 480.00

Av = 157079.633

fy = 444.44

s = 380.00

Vs2 is multiplied by Col2 = 0.83333333

s/d = 0.79166667

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 α is the angle of the crack direction (see KANEPE).

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

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

Vf = Min(|Vf(45, α)|, |Vf(-45, α)|), 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, $\gamma = 1.00$

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 Primary Member: Concrete Strength, fc = fcm = 20.00

Existing material of Primary 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, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i = 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

 Stepwise Properties

 Bending Moment, $M = -211400.249$
 Shear Force, $V_2 = -2806.138$
 Shear Force, $V_3 = 97.69573$
 Axial Force, $F = -9396.789$
 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, $D_bL = 17.71429$

 Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $\phi_{u,R} = \phi_u = 0.00485369$
 $\phi_u = \phi_y + \phi_p = 0.00485369$

 - Calculation of ϕ_y -

 $\phi_y = (M_y \cdot L_s / 3) / E_{eff} = 0.00485369$ ((4.29), Biskinis Phd))
 $M_y = 2.8210E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 2163.864
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$
 $factor = 0.30$
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9396.789$
 $E_c \cdot I_g = 1.3974E+014$

 Calculation of Yielding Moment M_y

 Calculation of ϕ_y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 3.8954822\text{E}-006$
 with $((10.1), \text{ASCE } 41-17) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 267.1762$
 $d = 557.00$
 $y = 0.38432516$
 $A = 0.02985235$
 $B = 0.0192346$
 with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9396.789$
 $b = 250.00$
 $" = 0.07719928$
 $y_{\text{comp}} = 8.1953653\text{E}-006$
 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), $efe = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 21019.039$
 $y = 0.38315844$
 $A = 0.02940687$
 $B = 0.01898202$
 with $Es = 200000.00$

 Calculation of ratio l_b/d

Lap Length: $l_d/d, \text{min} = 0.33351241$
 $l_b = 300.00$
 $l_d = 899.5167$
 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)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.03342$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 380.00$
 $n = 16.00$

 - 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 $V_y E / V_{CoI} O E = 0.60501747$
 $d = 557.00$
 $s = 0.00$
 $t = Av / (bw \cdot s) + 2 \cdot tf / bw \cdot (ffe / fs) = Av \cdot L_{\text{stir}} / (Ag \cdot s) + 2 \cdot tf / bw \cdot (ffe / fs) = 0.00$
 $Av = 78.53982$, 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 = 9396.789

Ag = 237500.00

f_{cE} = 20.00

f_{tE} = f_{ylE} = 0.00

pl = 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: (a)

Calculation No. 3

column C1, Floor 1

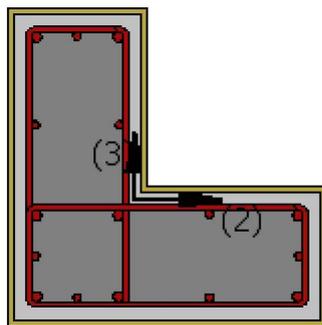
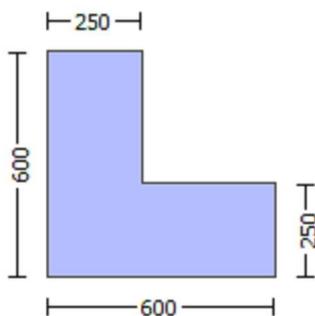
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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 Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$ 
Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 400.00$ 
Concrete Elasticity,  $E_c = 21019.039$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, 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,  $L = 3000.00$ 
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length  $l_o = l_b = 300.00$ 
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $NoDir = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $NL = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
EDGE -A-
Bending Moment,  $M_a = -211400.249$ 
Shear Force,  $V_a = 97.69573$ 
EDGE -B-
Bending Moment,  $M_b = -80623.075$ 
Shear Force,  $V_b = -97.69573$ 
BOTH EDGES
Axial Force,  $F = -9396.789$ 
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,  $Db_{L,ten} = 17.71429$ 
-----
-----

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity  $V_R = \phi V_n = 379585.591$ 
 $V_n ((10.3), ASCE 41-17) = k_n l \cdot V_{CoI0} = 379585.591$ 
 $V_{CoI} = 379585.591$ 
 $k_n l = 1.00$ 
displacement_ductility_demand = 0.0064437
-----

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)

$M/Vd = 4.00$

$\mu_u = 211400.249$

$V_u = 97.69573$

$d = 0.8 \cdot h = 480.00$

$N_u = 9396.789$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 66138.793$

where:

$V_{s1} = 66138.793$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 380.00$

V_{s1} is multiplied by $\text{Col1} = 0.83333333$

$s/d = 0.79166667$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 380.00$

V_{s2} is multiplied by $\text{Col2} = 0.00$

$s/d = 1.90$

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, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (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 δ / y

- Calculation of δ / y for END A -

for rotation axis 2 and integ. section (a)

From analysis, chord rotation $\theta = 3.1275712E-005$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00485369$ ((4.29), Biskinis Phd)

$M_y = 2.8210E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 2163.864

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

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9396.789$

$E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

```

y = Min( y_ten, y_com)
y_ten = 3.8954822E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^ 2/3) = 267.1762
d = 557.00
y = 0.38432516
A = 0.02985235
B = 0.0192346
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9396.789
b = 250.00
" = 0.07719928
y_comp = 8.1953653E-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 = 0.38315844
A = 0.02940687
B = 0.01898202
with Es = 200000.00

```

Calculation of ratio lb/d

Lap Length: $l_d/l_{d,min} = 0.33351241$

lb = 300.00

ld = 899.5167

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 = 1.03342

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

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

s = 380.00

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

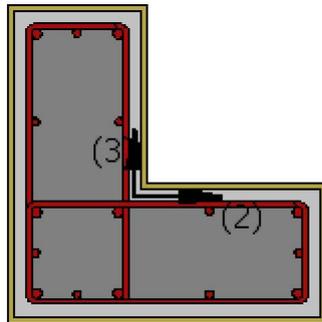
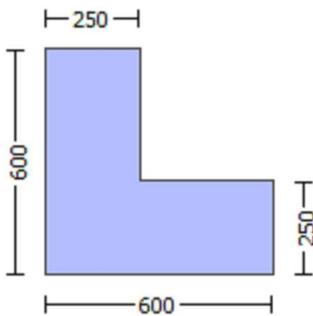
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

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, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00016213$

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, $V_e/V_r = 0.60501747$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.8119E+008$

$M_{u1+} = 3.8119E+008$, 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

$M_{u1-} = 2.0589E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.8119E+008$

$M_{u2+} = 3.8119E+008$, 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

$M_{u2-} = 2.0589E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.0933130E-005$

$M_u = 3.8119E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

ω (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.014005$

w_e ((5.4c), TBDY) = $a_{se} \cdot s_{h,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) \cdot (A_{conf,min}/A_{conf,max}), 0) = 0.00781147$

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

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

$A_{conf,min} = 3525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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) = $L_{stir} \cdot A_{stir}/(A_{sec} \cdot s) = 0.00127056$

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) = $L_{stir} \cdot A_{stir}/(A_{sec} \cdot s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

c = confinement factor = 1.0981

$y_1 = 0.0011992$

$sh_1 = 0.00414446$

$ft_1 = 345.3682$

$fy_1 = 287.8069$

$su_1 = 0.00414446$

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

Shear_factor = 1.00

lo/lou,min = lb/d = 0.26680993

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 = 287.8069

with Es1 = Es = 200000.00

y2 = 0.0011992

sh2 = 0.00414446

ft2 = 345.3682

fy2 = 287.8069

su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es2 = Es = 200000.00

yv = 0.0011992

shv = 0.00414446

ftv = 345.3682

fyv = 287.8069

suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.18050973

2 = Asl,com/(b*d)*(fs2/fc) = 0.08570966

v = Asl,mid/(b*d)*(fsv/fc) = 0.15973163

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) = 0.25103346

2 = Asl,com/(b*d)*(fs2/fc) = 0.11919574

v = Asl,mid/(b*d)*(fsv/fc) = 0.22213752

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) = 0.31943706

Mu = MRc (4.15) = 3.8119E+008

u = su (4.1) = 1.0933130E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$l_b = 300.00$

$l_d = 1124.396$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.03342$

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

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

$s = 380.00$

$n = 16.00$

Calculation of μ_1 -

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

$\mu = 9.0418593E-006$

$\mu = 2.0589E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, \mu_c) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu = 0.014005$

we ((5.4c), TBDY) = $\alpha * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

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

$f_x = 0.06888919$

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

$\alpha f = 0.24098246$

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), $\text{pf} = 2t_f/b_w = 0.008128$

$b_w = 250.00$

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), $\text{pf} = 2t_f/b_w = 0.008128$

$b_w = 250.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$$

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

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

$A_{conf,min} = 3525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0011992$$

$$sh_1 = 0.00414446$$

$$ft_1 = 345.3682$$

$$fy_1 = 287.8069$$

$$su_1 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.26680993$$

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

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.

$$\text{with } fs_1 = fs = 287.8069$$

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

$$y_2 = 0.0011992$$

$$sh_2 = 0.00414446$$

$$ft_2 = 345.3682$$

$$fy_2 = 287.8069$$

$$su_2 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.26680993$$

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

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.

$$\text{with } fs_2 = fs = 287.8069$$

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

$$y_v = 0.0011992$$

$$sh_v = 0.00414446$$

$$f_{tv} = 345.3682$$

$$f_{yv} = 287.8069$$

$$s_{uv} = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.26680993$$

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

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 γ_v , sh_v, f_{tv}, f_{yv} , it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_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.

$$\text{with } f_{sv} = f_s = 287.8069$$

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03571236$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07521239$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.06655485$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04193924$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08832659$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0781595$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.17708486$$

$$M_u = M_{Rc} (4.14) = 2.0589E+008$$

$$u = s_u (4.1) = 9.0418593E-006$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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: $f_y = 555.55$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of M_u2+

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

$$u = 1.0933130E-005$$

$$M_u = 3.8119E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \alpha = 0.014005$$

$$\alpha_w \text{ ((5.4c), TBDY) } = \alpha_s * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$f_y = 0.06888919$$

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

$$\alpha_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_s = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

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

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

$$y1 = 0.0011992$$

$$sh1 = 0.00414446$$

$$ft1 = 345.3682$$

$$fy1 = 287.8069$$

$$su1 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.26680993$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs1 = fs = 287.8069$$

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

$$y2 = 0.0011992$$

$$sh2 = 0.00414446$$

$$ft2 = 345.3682$$

$$fy2 = 287.8069$$

$$su2 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.26680993$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs2 = fs = 287.8069$$

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

$$yv = 0.0011992$$

$$shv = 0.00414446$$

$$ftv = 345.3682$$

$$fyv = 287.8069$$

$$suv = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.26680993$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = fs = 287.8069$$

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.18050973$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.08570966$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.15973163$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

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

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

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.25103346$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.11919574$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.22213752$$

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

---->

s_u (4.8) = 0.31943706

$\mu_u = M_{Rc}$ (4.15) = 3.8119E+008

$u = s_u$ (4.1) = 1.0933130E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$l_b = 300.00$

$l_d = 1124.396$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.03342$

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

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

$s = 380.00$

$n = 16.00$

Calculation of μ_u

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

$u = 9.0418593E-006$

$\mu_u = 2.0589E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\alpha = 0.014005$

where α_c ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

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 $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.24098246$

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 $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

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 = $Max(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.00781147$

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 = 3525.00 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 = $Min(psh,x, psh,y) = 0.00127056$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
Lstir (Length of stirrups along Y) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 380.00
fywe = 555.55
fce = 20.00

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

y1 = 0.0011992
sh1 = 0.00414446
ft1 = 345.3682
fy1 = 287.8069
su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = $l_b/l_d = 0.26680993$

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.

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 fs₁ = fs = 287.8069

with Es₁ = Es = 200000.00

y2 = 0.0011992
sh2 = 0.00414446
ft2 = 345.3682
fy2 = 287.8069
su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es2 = Es = 200000.00

yv = 0.0011992

shv = 0.00414446

ftv = 345.3682

fyv = 287.8069

suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03571236

2 = Asl,com/(b*d)*(fs2/fc) = 0.07521239

v = Asl,mid/(b*d)*(fsv/fc) = 0.06655485

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) = 0.04193924

2 = Asl,com/(b*d)*(fs2/fc) = 0.08832659

v = Asl,mid/(b*d)*(fsv/fc) = 0.0781595

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.17708486

Mu = MRc (4.14) = 2.0589E+008

u = su (4.1) = 9.0418593E-006

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.26680993

lb = 300.00

ld = 1124.396

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 = 1.03342

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 = 380.00

$$n = 16.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 420034.424$

Calculation of Shear Strength at edge 1, $V_{r1} = 420034.424$

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

$$V_{\text{ColO}} = 420034.424$$

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

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

$$= 1 \text{ (normal-weight concrete)}$$

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

$$M/Vd = 4.00$$

$$M_u = 47.24078$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 73486.813$$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s1} is multiplied by $\text{Col1} = 0.83333333$

$$s/d = 0.79166667$$

$V_{s2} = 0.00$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s2} is multiplied by $\text{Col2} = 0.00$

$$s/d = 1.90$$

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

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

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

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ 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 α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \theta = 45^\circ + 90^\circ = 135^\circ$$

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

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

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

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

$$E_f = 64828.00$$

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

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

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

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 420034.424$

$$V_{r2} = V_{\text{Col}} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{\text{ColO}}$$

$$V_{\text{ColO}} = 420034.424$$

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

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)

$M/Vd = 4.00$

$\mu_u = 47.24081$

$\nu_u = 0.00016213$

$d = 0.8 \cdot h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $\text{Col1} = 0.83333333$

$s/d = 0.79166667$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $\text{Col2} = 0.00$

$s/d = 1.90$

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: $\theta = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a)|)$, 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, $\phi = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length lo = 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 , $V_e/V_r = 0.60501747$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.8119\text{E}+008$

$\mu_{1+} = 3.8119\text{E}+008$, 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

$\mu_{1-} = 2.0589\text{E}+008$, 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.8119\text{E}+008$

$\mu_{2+} = 3.8119\text{E}+008$, 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

$\mu_{2-} = 2.0589\text{E}+008$, 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 μ_{1+}

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

u = 1.0933130E-005
Mu = 3.8119E+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: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.014005$

we ((5.4c), TBDY) = $ase * sh_{,min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.0689719$

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 = $\text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$

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

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

$A_{conf,min} = 3525.00$ is 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).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00127056$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 380.00$
 $fy_{we} = 555.55$
 $f_{ce} = 20.00$
 From ((5.A.5), TBDY), TBDY: $cc = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $y_1 = 0.0011992$
 $sh_1 = 0.00414446$
 $ft_1 = 345.3682$
 $fy_1 = 287.8069$
 $su_1 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.26680993$
 $su_1 = 0.4 * esu_1 \text{ nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu_1 \text{ nominal} = 0.08$,
 For calculation of $esu_1 \text{ nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 287.8069$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 0.26680993$
 $su_2 = 0.4 * esu_2 \text{ nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu_2 \text{ nominal} = 0.08$,
 For calculation of $esu_2 \text{ nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 287.8069$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $fy_v = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.26680993$
 $suv = 0.4 * esuv \text{ nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv \text{ nominal} = 0.08$,
 considering characteristic value $fsyv = fs_v/1.2$, 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 $fsy_v = fs_v/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_v = fs = 287.8069$
 with $Es_v = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.18050973$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.08570966$
 $v = Asl, \text{mid} / (b * d) * (fs_v / fc) = 0.15973163$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, \text{TBDY}) = 21.96205$
 $cc (5A.5, \text{TBDY}) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.25103346$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.11919574$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.22213752$$

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

--->

$$s_u(4.8) = 0.31943706$$

$$M_u = M_{Rc}(4.15) = 3.8119E+008$$

$$u = s_u(4.1) = 1.0933130E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of M_u1 -

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

$$u = 9.0418593E-006$$

$$M_u = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} \cdot \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e((5.4c), TBDY) = a_{se} \cdot s_{h, min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

c = confinement factor = 1.0981

$$y_1 = 0.0011992$$

$$sh_1 = 0.00414446$$

$$ft_1 = 345.3682$$

$$fy_1 = 287.8069$$

$$su_1 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.26680993$$

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

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 $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$$y_2 = 0.0011992$$

$$sh_2 = 0.00414446$$

$$ft_2 = 345.3682$$

$$fy_2 = 287.8069$$

$$su_2 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.26680993$

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

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 $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$su_v = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.26680993$

$su_v = 0.4 * esu_{v,nominal} ((5.5), TBDY) = 0.032$

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

considering characteristic value $fsy_v = fsv/1.2$, 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 $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 287.8069$

with $Es_v = Es = 200000.00$

$1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.03571236$

$2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.07521239$

$v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.06655485$

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 $= 1.0981$

$1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.04193924$

$2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.08832659$

$v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.0781595$

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

--->

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

--->

$su (4.9) = 0.17708486$

$Mu = MRc (4.14) = 2.0589E+008$

$u = su (4.1) = 9.0418593E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$l_b = 300.00$

$l_d = 1124.396$

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 $fc^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.03342$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of μ_{2+}

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

$$\mu = 1.0933130E-005$$

$$\mu_{2+} = 3.8119E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_{2+}: \mu_{2+}^* = \text{shear_factor} * \text{Max}(\mu_{2+}, \mu_{2+}^c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{2+}^c = 0.014005$$

$$\mu_{2+}^* \text{ (5.4c, TBDY)} = a_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

where $f = a_{se} * p_f * f_{fe} / f_{ce}$ 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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$\text{psh}_x \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00127056$$

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

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

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

$$\text{psh}_y \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0011992$$

$$sh_1 = 0.00414446$$

$$ft_1 = 345.3682$$

$$fy_1 = 287.8069$$

$$su_1 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 0.26680993$$

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

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

$$\text{with } fs_1 = fs = 287.8069$$

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

$$y_2 = 0.0011992$$

$$sh_2 = 0.00414446$$

$$ft_2 = 345.3682$$

$$fy_2 = 287.8069$$

$$su_2 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/lb_{,min} = 0.26680993$$

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

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

$$\text{with } fs_2 = fs = 287.8069$$

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

$$y_v = 0.0011992$$

$$sh_v = 0.00414446$$

$$ft_v = 345.3682$$

$$fy_v = 287.8069$$

$$su_v = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 0.26680993$$

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

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

$$\text{with } fsv = fs = 287.8069$$

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

$$1 = Asl_{,ten} / (b * d) * (fs_1 / fc) = 0.18050973$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08570966$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.15973163$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.25103346$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11919574$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.22213752$$

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

--->

$$s_u (4.8) = 0.31943706$$

$$M_u = M_{Rc} (4.15) = 3.8119E+008$$

$$u = s_u (4.1) = 1.0933130E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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: $f_y = 555.55$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of M_u2 -

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

$$u = 9.0418593E-006$$

$$M_u = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$\text{where ((5.4c), TBDY) } = a_s e^* s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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, $t_f = N_L * t * \cos(b_1) = 1.016$

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0011992$$

$$sh_1 = 0.00414446$$

$$ft_1 = 345.3682$$

$$fy_1 = 287.8069$$

$$su_1 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.26680993$$

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

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

with $fs1 = fs = 287.8069$

with $Es1 = Es = 200000.00$

$y2 = 0.0011992$

$sh2 = 0.00414446$

$ft2 = 345.3682$

$fy2 = 287.8069$

$su2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

$lo/lou, min = lb/lb, min = 0.26680993$

$su2 = 0.4 \cdot esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

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

with $fs2 = fs = 287.8069$

with $Es2 = Es = 200000.00$

$yv = 0.0011992$

$shv = 0.00414446$

$ftv = 345.3682$

$fyv = 287.8069$

$suv = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

$lo/lou, min = lb/ld = 0.26680993$

$suv = 0.4 \cdot esuv_nominal$ ((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 $fsv = fs = 287.8069$

with $Esv = Es = 200000.00$

$1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.03571236$

$2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.07521239$

$v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.06655485$

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

$1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.04193924$

$2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.08832659$

$v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.0781595$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

su (4.9) = 0.17708486

$Mu = MRc$ (4.14) = 2.0589E+008

$u = su$ (4.1) = 9.0418593E-006

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$

$lb = 300.00$

$ld = 1124.396$

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: $f_y = 555.55$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 420034.424$

Calculation of Shear Strength at edge 1, $V_{r1} = 420034.424$

$$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$$

$$V_{Col0} = 420034.424$$

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

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).

$$= 1 \text{ (normal-weight concrete)}$$

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

$$M/Vd = 4.00$$

$$M_u = 47.23669$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 73486.813$$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s1} is multiplied by $Col1 = 0.00$

$$s/d = 1.90$$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s2} is multiplied by $Col2 = 0.83333333$

$$s/d = 0.79166667$$

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

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

$w_f/s_f = 1$ (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 α 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, $V_{r2} = 420034.424$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 420034.424$
 $knl = 1$ (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: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 200.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.90$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$d = 480.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 380.00$

V_{s2} is multiplied by $Col2 = 0.83333333$

$s/d = 0.79166667$

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

$f = 0.95$, 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 $V_f(a)$, 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: $a = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, a)|, |V_f(-45, a)|)$, 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: $V_s + V_f \leq 356502.845$

$bw = 250.00$

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, $\phi = 1.00$
 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 Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 Max Height, $H_{max} = 600.00$
 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, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i = 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -8.5294E+006$
 Shear Force, $V_2 = -2806.138$
 Shear Force, $V_3 = 97.69573$
 Axial Force, $F = -9396.789$
 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 $u_{,R} = \phi \cdot u = 0.00681789$
 $u = y + p = 0.00681789$

- Calculation of y -

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00681789$ ((4.29), Biskinis Phd)
 $M_y = 2.8210E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3039.54
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$
 $factor = 0.30$
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9396.789$
 $E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to Annex 7 -

 $y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 3.8954822\text{E-}006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 267.1762$
 $d = 557.00$
 $y = 0.38432516$
 $A = 0.02985235$
 $B = 0.0192346$
with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9396.789$
 $b = 250.00$
 $\rho = 0.07719928$
 $y_{\text{comp}} = 8.1953653\text{E-}006$
with $f_c^* (12.3, (ACI 440)) = 20.42407$
 $f_c = 20.00$
 $fl = 0.62098351$
 $b = b_{\text{max}} = 600.00$
 $h = h_{\text{max}} = 600.00$
 $Ag = 237500.00$
 $g = pt + pc + pv = 0.02959978$
 $rc = 40.00$
 $A_e/A_c = 0.21783041$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38315844$
 $A = 0.02940687$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio l_b/d

Lap Length: $l_d/l_d, \text{min} = 0.33351241$

$l_b = 300.00$

$l_d = 899.5167$

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: $f_y = 444.44$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.03342$

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

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

$s = 380.00$

$n = 16.00$

- Calculation of ρ_p -

From table 10-8: $\rho_p = 0.00$

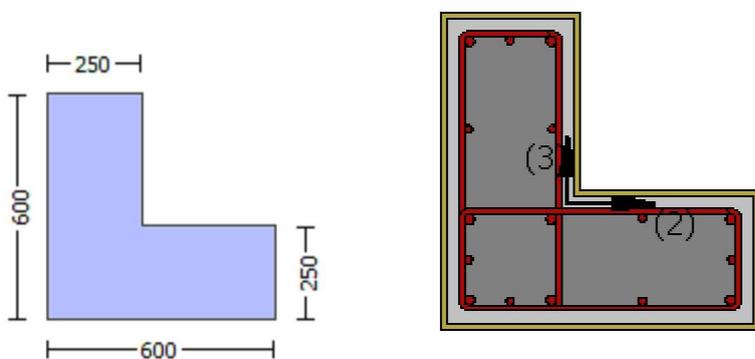
with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
 shear control ratio $V_{yE}/V_{CoIE} = 0.60501747$
 $d = 557.00$
 $s = 0.00$
 $t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$
 $A_v = 78.53982$, 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.
 $NUD = 9396.789$
 $A_g = 237500.00$
 $f_{cE} = 20.00$
 $f_{ytE} = f_{ylE} = 0.00$
 $\rho_l = Area_{Tot_Long_Rein}/(b*d) = 0.02959978$
 $b = 250.00$
 $d = 557.00$
 $f_{cE} = 20.00$

 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, $\gamma = 1.00$
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 Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ 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, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -8.5294E+006$
Shear Force, $V_a = -2806.138$
EDGE -B-
Bending Moment, $M_b = 108099.704$
Shear Force, $V_b = 2806.138$
BOTH EDGES
Axial Force, $F = -9396.789$
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: $As_{c,com} = 829.3805$
-Middle: $As_{mid} = 1545.664$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 440305.344$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoIO} = 440305.344$
 $V_{CoI} = 440305.344$
 $k_n = 1.00$
displacement_ductility_demand = 0.04673752

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ ϕV_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)
 $M/Vd = 2.00$
 $M_u = 108099.704$
 $V_u = 2806.138$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9396.789$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 66138.793$
where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.90$
 $V_{s2} = 66138.793$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
 V_{s2} is multiplied by $Col2 = 0.83333333$
 $s/d = 0.79166667$
 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 $(\cot \theta + \csc \theta) \sin \theta$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, a_1)$, 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, $t_{f1} = N_L \cdot t / N_{Dir} = 1.016$
 $d_{fv} = d$ (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 δ / y

- Calculation of δ / y for END B -
for rotation axis 3 and integ. section (b)

From analysis, chord rotation $\theta = 3.1450600E-005$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00067292$ ((4.29), Biskinis Phd)
 $M_y = 2.8210E+008$
 $L_s = M/V$ (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
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9396.789$

$$E_c \cdot I_g = 1.3974E+014$$

Calculation of Yielding Moment M_y

Calculation of γ and M_y according to Annex 7 -

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

$$y_{\text{ten}} = 3.8954822E-006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) \quad f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 267.1762$$

$$d = 557.00$$

$$y = 0.38432516$$

$$A = 0.02985235$$

$$B = 0.0192346$$

$$\text{with } p_t = 0.01254381$$

$$p_c = 0.00595605$$

$$p_v = 0.01109992$$

$$N = 9396.789$$

$$b = 250.00$$

$$" = 0.07719928$$

$$y_{\text{comp}} = 8.1953653E-006$$

$$\text{with } f_c^* (12.3, \text{ACI 440}) = 20.42407$$

$$f_c = 20.00$$

$$f_l = 0.62098351$$

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

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

$$A_g = 237500.00$$

$$g = p_t + p_c + p_v = 0.02959978$$

$$r_c = 40.00$$

$$A_e/A_c = 0.21783041$$

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

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.38315844$$

$$A = 0.02940687$$

$$B = 0.01898202$$

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

Calculation of ratio l_b/d

$$\text{Lap Length: } l_d/d, \text{min} = 0.33351241$$

$$l_b = 300.00$$

$$l_d = 899.5167$$

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

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 444.44$$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

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

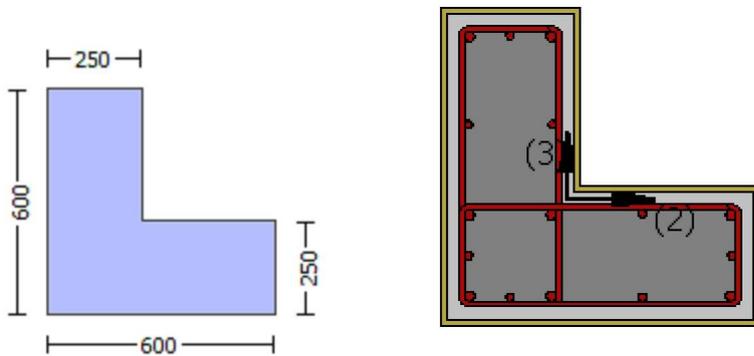
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

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, $\phi = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
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: $A_{sl,t} = 0.00$
-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 , $V_e/V_r = 0.60501747$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 3.8119E+008$
 $Mu_{1+} = 3.8119E+008$, 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
 $Mu_{1-} = 2.0589E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 3.8119E+008$
 $Mu_{2+} = 3.8119E+008$, 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
 $Mu_{2-} = 2.0589E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.0933130E-005$
 $M_u = 3.8119E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$$

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

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

$A_{conf,min} = 3525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0011992$$

$$s_{h1} = 0.00414446$$

$$f_{t1} = 345.3682$$

$f_{y1} = 287.8069$
 $s_{u1} = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,u,min} = l_b/l_d = 0.26680993$
 $s_{u1} = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$
 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 $f_{s1} = f_s/1.2$, 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 $f_{s1} = f_s = 287.8069$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $f_{y2} = 287.8069$
 $s_{u2} = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,u,min} = l_b/l_{b,min} = 0.26680993$
 $s_{u2} = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$
 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 $f_{s2} = f_s/1.2$, 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 $f_{s2} = f_s = 287.8069$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $f_{y_v} = 287.8069$
 $s_{u_v} = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,u,min} = l_b/l_d = 0.26680993$
 $s_{u_v} = 0.4 * e_{s_{u_v}}_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{s_{u_v}}_nominal = 0.08$,
 considering characteristic value $f_{s_{u_v}} = f_{s_v}/1.2$, from table 5.1, TBDY
 For calculation of $e_{s_{u_v}}_nominal$ and y_v, sh_v, ft_v, f_{y_v} , it is considered
 characteristic value $f_{s_{u_v}} = f_{s_v}/1.2$, 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 $f_{s_v} = f_s = 287.8069$
 with $E_{s_v} = E_s = 200000.00$
 $1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.18050973$
 $2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.08570966$
 $v = A_{s1,mid}/(b*d)*(f_{s_v}/f_c) = 0.15973163$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.25103346$
 $2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.11919574$
 $v = A_{s1,mid}/(b*d)*(f_{s_v}/f_c) = 0.22213752$
 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
 --->
 $s_u (4.8) = 0.31943706$

$$\begin{aligned} \mu_u &= M/R_c(4.15) = 3.8119E+008 \\ u &= s_u(4.1) = 1.0933130E-005 \end{aligned}$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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: $f_y = 555.55$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of μ_{u1} -

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

$$u = 9.0418593E-006$$

$$\mu_u = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e((5.4c), \text{ TBDY}) = a_s e^* \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0011992$$

$$sh_1 = 0.00414446$$

$$ft_1 = 345.3682$$

$$fy_1 = 287.8069$$

$$su_1 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{o,min} = l_b / l_d = 0.26680993$$

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

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

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

$$\text{with } fs_1 = fs = 287.8069$$

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

$$y_2 = 0.0011992$$

$$sh_2 = 0.00414446$$

$$ft_2 = 345.3682$$

$$fy_2 = 287.8069$$

$$su_2 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{o,min} = l_b / l_{b,min} = 0.26680993$$

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

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

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2 / 1.2$, 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 $f_{s2} = f_s = 287.8069$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $fy_v = 287.8069$
 $su_v = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.26680993$
 $su_v = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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 $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 287.8069$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.03571236$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07521239$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.06655485$

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.04193924$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.08832659$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.0781595$

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

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17708486$
 $Mu = MRc (4.14) = 2.0589E+008$
 $u = su (4.1) = 9.0418593E-006$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$
 $l_b = 300.00$
 $l_d = 1124.396$
 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)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.03342$
 $A_{tr} = Min(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 380.00$
 $n = 16.00$

 Calculation of Mu_{2+}

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

$$u = 1.0933130E-005$$

$$Mu = 3.8119E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.014005$$

$$\phi_{we} \text{ ((5.4c), TBDY)} = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.0689719$$

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

$$\phi_x = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$\phi_y = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$\phi_{sh, \min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00127056$$

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

$$\phi_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

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

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

$$\phi_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 380.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.0981

y1 = 0.0011992

sh1 = 0.00414446

ft1 = 345.3682

fy1 = 287.8069

su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es1 = Es = 200000.00

y2 = 0.0011992

sh2 = 0.00414446

ft2 = 345.3682

fy2 = 287.8069

su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es2 = Es = 200000.00

yv = 0.0011992

shv = 0.00414446

ftv = 345.3682

fyv = 287.8069

suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.18050973

2 = Asl,com/(b*d)*(fs2/fc) = 0.08570966

v = Asl,mid/(b*d)*(fsv/fc) = 0.15973163

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.25103346$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11919574$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.22213752$$

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

--->
 μ_u (4.8) = 0.31943706
 $M_u = M_{Rc}$ (4.15) = 3.8119E+008
 $u = \mu_u$ (4.1) = 1.0933130E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of μ_u

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

$$u = 9.0418593E-006$$

$$M_u = 2.0589E+008$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.014005$$

$$\text{we ((5.4c), TBDY) } = a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00781147$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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)

$p_{sh,x} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

c = confinement factor = 1.0981

$y_1 = 0.0011992$

$sh_1 = 0.00414446$

$ft_1 = 345.3682$

$fy_1 = 287.8069$

$su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.26680993$

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

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 $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$

$sh_2 = 0.00414446$

$ft_2 = 345.3682$

$f_y2 = 287.8069$
 $s_u2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.26680993$
 $s_u2 = 0.4 * e_{su2_nominal} ((5.5), TBDY) = 0.032$
 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.
 with $f_{s2} = f_s = 287.8069$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $f_{y_v} = 287.8069$
 $s_{u_v} = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.26680993$
 $s_{u_v} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 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_{y_v} , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_y1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 287.8069$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.03571236$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07521239$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.06655485$

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.04193924$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.08832659$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.0781595$

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

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

$s_u (4.9) = 0.17708486$
 $M_u = M_{Rc} (4.14) = 2.0589E+008$
 $u = s_u (4.1) = 9.0418593E-006$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$
 $l_b = 300.00$
 $l_d = 1124.396$
 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)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

$$\text{Calculation of Shear Strength } V_r = \text{Min}(V_{r1}, V_{r2}) = 420034.424$$

$$\text{Calculation of Shear Strength at edge 1, } V_{r1} = 420034.424$$

$$V_{r1} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{CoI0}$$

$$V_{CoI0} = 420034.424$$

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

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'

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

$$= 1 \text{ (normal-weight concrete)}$$

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

$$M/Vd = 4.00$$

$$\mu_u = 47.24078$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 73486.813$$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s1} is multiplied by $Col1 = 0.83333333$

$$s/d = 0.79166667$$

$V_{s2} = 0.00$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s2} is multiplied by $Col2 = 0.00$

$$s/d = 1.90$$

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

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

$w_f/s_f = 1$ (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 α 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: $\alpha = b1 + 90^\circ = 90.00$

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

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

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

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

$$E_f = 64828.00$$

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

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

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

$$b_w = 250.00$$

$$\text{Calculation of Shear Strength at edge 2, } V_{r2} = 420034.424$$

$$V_{r2} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{CoI0}$$

$$V_{CoI0} = 420034.424$$

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

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 = 73486.813

where:

Vs1 = 73486.813 is calculated for section web, with:

d = 480.00

Av = 157079.633

fy = 444.44

s = 380.00

Vs1 is multiplied by Col1 = 0.83333333

s/d = 0.79166667

Vs2 = 0.00 is calculated for section flange, with:

d = 200.00

Av = 157079.633

fy = 444.44

s = 380.00

Vs2 is multiplied by Col2 = 0.00

s/d = 1.90

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 α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(α), is implemented for every different fiber orientation ai,

as well as for 2 crack directions, $\alpha = 45^\circ$ 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, $\gamma = 1.00$

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

Consequently:

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

Existing material of Primary 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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

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: $A_{sl} = 0.00$

-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 , $V_e/V_r = 0.60501747$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.8119E+008$

$\mu_{1+} = 3.8119E+008$, 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

$\mu_{1-} = 2.0589E+008$, 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.8119E+008$

$\mu_{2+} = 3.8119E+008$, 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

$\mu_{2-} = 2.0589E+008$, 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 μ_{1+}

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

$$\mu = 1.0933130E-005$$

$$\mu_u = 3.8119E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.014005$$

$$\mu_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$f_y = 0.06888919$$

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

$$\alpha_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$$

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

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

$A_{conf,min} = 3525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$\text{psh,y ((5.4d), TBDY)} = \text{Lstir} \cdot \text{Astir} / (\text{Asec} \cdot \text{s}) = 0.00127056$$

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

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

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

$$\text{s} = 380.00$$

$$\text{fywe} = 555.55$$

$$\text{fce} = 20.00$$

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

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

$$\text{y1} = 0.0011992$$

$$\text{sh1} = 0.00414446$$

$$\text{ft1} = 345.3682$$

$$\text{fy1} = 287.8069$$

$$\text{su1} = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/l} = 0.26680993$$

$$\text{su1} = 0.4 \cdot \text{esu1_nominal ((5.5), TBDY)} = 0.032$$

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

$$\text{with fs1} = \text{fs} = 287.8069$$

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

$$\text{y2} = 0.0011992$$

$$\text{sh2} = 0.00414446$$

$$\text{ft2} = 345.3682$$

$$\text{fy2} = 287.8069$$

$$\text{su2} = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb}/\text{lb,min} = 0.26680993$$

$$\text{su2} = 0.4 \cdot \text{esu2_nominal ((5.5), TBDY)} = 0.032$$

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

$$\text{with fs2} = \text{fs} = 287.8069$$

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

$$\text{yv} = 0.0011992$$

$$\text{shv} = 0.00414446$$

$$\text{ftv} = 345.3682$$

$$\text{fyv} = 287.8069$$

$$\text{su} = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb}/\text{l} = 0.26680993$$

$$\text{su} = 0.4 \cdot \text{esuv_nominal ((5.5), TBDY)} = 0.032$$

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

$$\text{with fsv} = \text{fs} = 287.8069$$

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

$$1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.18050973$$

$$2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.08570966$$

$$\text{v} = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.15973163$$

and confined core properties:

$$\text{b} = 190.00$$

$$\text{d} = 527.00$$

$$\text{d}' = 13.00$$

$$\text{fcc (5A.2, TBDY)} = 21.96205$$

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

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

$$1 = \text{Asl,ten}/(b*d)*(fs1/fc) = 0.25103346$$

$$2 = \text{Asl,com}/(b*d)*(fs2/fc) = 0.11919574$$

$$v = \text{Asl,mid}/(b*d)*(fsv/fc) = 0.22213752$$

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

---->
 $su \text{ (4.8)} = 0.31943706$

$$Mu = MRc \text{ (4.15)} = 3.8119E+008$$

$$u = su \text{ (4.1)} = 1.0933130E-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$

$$lb = 300.00$$

$$ld = 1124.396$$

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

$$= 1$$

$$db = 18.00$$

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

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of $Mu1$ -

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

$$u = 9.0418593E-006$$

$$Mu = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$fc = 20.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.014005$$

$$\text{we ((5.4c), TBDY) } = ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.0689719$$

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 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, $tf = NL*t*Cos(b1) = 1.016$
 $fu,f = 1055.00$
 $Ef = 64828.00$
 $u,f = 0.015$
 $ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.00781147$
The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.
 $A_{conf,min} = 3525.00$ is 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 $b^2/6$ as defined at (A.2).
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00127056$
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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
 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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

 $s = 380.00$
 $fywe = 555.55$
 $fce = 20.00$
From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $y1 = 0.0011992$
 $sh1 = 0.00414446$
 $ft1 = 345.3682$
 $fy1 = 287.8069$
 $su1 = 0.00414446$
using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.26680993$
 $su1 = 0.4*esu1_nominal$ ((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 $fs1 = fs = 287.8069$
with $Es1 = Es = 200000.00$
 $y2 = 0.0011992$

$sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 0.26680993$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = fs = 287.8069$
 with $Es_2 = Es = 200000.00$
 $yv = 0.0011992$
 $shv = 0.00414446$
 $ftv = 345.3682$
 $fyv = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 0.26680993$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 287.8069$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.03571236$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.07521239$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.06655485$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.04193924$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.08832659$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.0781595$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs_y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17708486$
 $Mu = MRc (4.14) = 2.0589E+008$
 $u = su (4.1) = 9.0418593E-006$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$
 $lb = 300.00$
 $ld = 1124.396$
 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 = 1.03342
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 local axis
s = 380.00
n = 16.00

Calculation of Mu2+

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
u = 1.0933130E-005
Mu = 3.8119E+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 μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_s) = 0.014005$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_c = 0.014005$
 μ_s ((5.4c), TBDY) = $\text{ase} * \text{sh_min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$
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_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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

a_f = 0.24098246

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

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

f_u,f = 1055.00

E_f = 64828.00

u_f = 0.015

ase = $\text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$

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

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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 = 3525.00 is 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.

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

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00127056$

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)

 $psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

 $psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 380.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.0981

y1 = 0.0011992

sh1 = 0.00414446

ft1 = 345.3682

fy1 = 287.8069

su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 287.8069

with Es1 = Es = 200000.00

y2 = 0.0011992

sh2 = 0.00414446

ft2 = 345.3682

fy2 = 287.8069

su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2, ft2, fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

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

with fs2 = fs = 287.8069

with Es2 = Es = 200000.00

yv = 0.0011992

shv = 0.00414446

ftv = 345.3682

fyv = 287.8069

suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 $fsv = fs = 287.8069$

with $Esv = Es = 200000.00$

$1 = Asl,ten/(b \cdot d) \cdot (fs1/fc) = 0.18050973$

$2 = Asl,com/(b \cdot d) \cdot (fs2/fc) = 0.08570966$

$v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.15973163$

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

$1 = Asl,ten/(b \cdot d) \cdot (fs1/fc) = 0.25103346$

$2 = Asl,com/(b \cdot d) \cdot (fs2/fc) = 0.11919574$

$v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.22213752$

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) = 0.31943706

$Mu = MRc$ (4.15) = 3.8119E+008

$u = su$ (4.1) = 1.0933130E-005

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$

$lb = 300.00$

$ld = 1124.396$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 1.03342$

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

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

$s = 380.00$

$n = 16.00$

Calculation of $Mu2$ -

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

$u = 9.0418593E-006$

$Mu = 2.0589E+008$

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 : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.014005$

we ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

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

$b_{max} = 600.00$

$h_{max} = 600.00$

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

$bw = 250.00$

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

 $f_y = 0.06888919$

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), $f_{f,e} = 703.4155$

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$

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

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

$A_{conf,min} = 3525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

c = confinement factor = 1.0981

$y1 = 0.0011992$

$sh1 = 0.00414446$

$ft1 = 345.3682$

$fy1 = 287.8069$

$su1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es1 = Es = 200000.00

y2 = 0.0011992

sh2 = 0.00414446

ft2 = 345.3682

fy2 = 287.8069

su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es2 = Es = 200000.00

yv = 0.0011992

shv = 0.00414446

ftv = 345.3682

fyv = 287.8069

suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03571236

2 = Asl,com/(b*d)*(fs2/fc) = 0.07521239

v = Asl,mid/(b*d)*(fsv/fc) = 0.06655485

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) = 0.04193924

2 = Asl,com/(b*d)*(fs2/fc) = 0.08832659

v = Asl,mid/(b*d)*(fsv/fc) = 0.0781595

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.17708486

Mu = MRc (4.14) = 2.0589E+008

u = su (4.1) = 9.0418593E-006

Calculation of ratio lb/d

Lap Length: $l_b/l_d = 0.26680993$

$l_b = 300.00$

$l_d = 1124.396$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.03342$

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

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

$s = 380.00$

$n = 16.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 420034.424$

Calculation of Shear Strength at edge 1, $V_{r1} = 420034.424$

$V_{r1} = V_{CoI}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{CoI0}$

$V_{CoI0} = 420034.424$

$k_{nl} = 1$ (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: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.90$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $Col2 = 0.83333333$

$s/d = 0.79166667$

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 α 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: $\alpha = 45^\circ$ and $\alpha = 90^\circ$

$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$, 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} = 420034.424
 $V_{r2} = V_{CoI}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{CoI0}$
 V_{CoI0} = 420034.424
 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
 μ_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: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

V_{s1} = 0.00 is calculated for section web, with:

d = 200.00
 A_v = 157079.633
 f_y = 444.44
 s = 380.00

V_{s1} is multiplied by $Col1$ = 0.00

s/d = 1.90

V_{s2} = 73486.813 is calculated for section flange, with:

d = 480.00
 A_v = 157079.633
 f_y = 444.44
 s = 380.00

V_{s2} is multiplied by $Col2$ = 0.83333333

s/d = 0.79166667

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 θ 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 α_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

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

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, 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, $\gamma = 1.00$
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 Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 600.00$
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, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -80623.075$
Shear Force, $V_2 = 2806.138$
Shear Force, $V_3 = -97.69573$
Axial Force, $F = -9396.789$
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 $u_{,R} = \gamma \cdot u = 0.00185108$
 $u = \gamma \cdot u + p = 0.00185108$

- Calculation of γ -

$\gamma = (M \cdot L_s / 3) / E_{eff} = 0.00185108$ ((4.29), Biskinis Phd))
 $M_y = 2.8210E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 825.2466
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 = 9396.789
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})
 $y_{ten} = 3.8954822E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25*f_y*(l_b/d)^{2/3}) = 267.1762$
d = 557.00
y = 0.38432516
A = 0.02985235
B = 0.0192346
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9396.789
b = 250.00
" = 0.07719928
 $y_{comp} = 8.1953653E-006$
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 = 0.38315844
A = 0.02940687
B = 0.01898202
with Es = 200000.00

Calculation of ratio l_b/d

Lap Length: $l_d/l_d, \text{min} = 0.33351241$
 $l_b = 300.00$
 $l_d = 899.5167$
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: $f_y = 444.44$
 $f_c' = 20.00$, 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
Ktr = 1.03342
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
s = 380.00
n = 16.00

- Calculation of ρ -

From table 10-8: $\rho = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_{yE}/V_{CoIE} = 0.60501747$

$d = 557.00$

$s = 0.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$

$A_v = 78.53982$, 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.

$NUD = 9396.789$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

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

At local axis: 2

Integration Section: (b)

Calculation No. 7

column C1, Floor 1

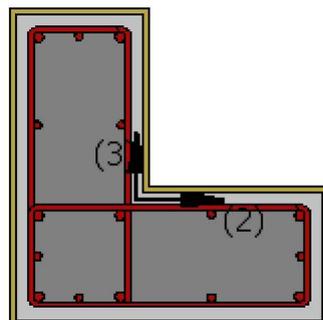
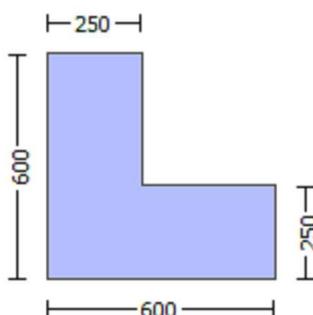
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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, $\gamma = 1.00$

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 Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ 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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

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, $M_a = -211400.249$

Shear Force, $V_a = 97.69573$

EDGE -B-

Bending Moment, $M_b = -80623.075$

Shear Force, $V_b = -97.69573$

BOTH EDGES

Axial Force, $F = -9396.789$

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 $V_R = \phi V_n = 440305.344$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI} = 440305.344$
 $V_{CoI} = 440305.344$
 $k_n = 1.00$
 $displacement_ductility_demand = 1.1634508E-005$

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)
 $M/Vd = 2.00$
 $\mu_u = 80623.075$
 $V_u = 97.69573$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9396.789$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 66138.793$

where:

$V_{s1} = 66138.793$ is calculated for section web, with:

$d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$

V_{s1} is multiplied by $Col1 = 0.83333333$

$s/d = 0.79166667$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.90$

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 θ 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 α_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 $\alpha = 90^\circ$

$V_f = \text{Min}(|V_f(45, 90)|, |V_f(-45, 90)|)$, 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 ϕ / y

- Calculation of ϕ / y for END B -

for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\phi = 2.1536437E-008$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00185108$ ((4.29), Biskinis Phd))

$M_y = 2.8210E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 825.2466

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 = 9396.789
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})
 $y_{ten} = 3.8954822E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25*f_y*(l_b/d)^{2/3}) = 267.1762$
d = 557.00
y = 0.38432516
A = 0.02985235
B = 0.0192346
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9396.789
b = 250.00
" = 0.07719928
 $y_{comp} = 8.1953653E-006$
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 = 0.38315844
A = 0.02940687
B = 0.01898202
with Es = 200000.00

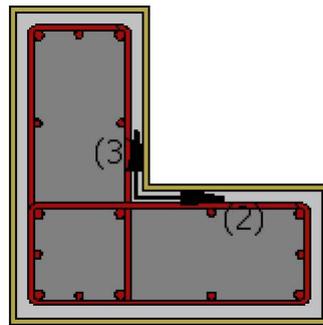
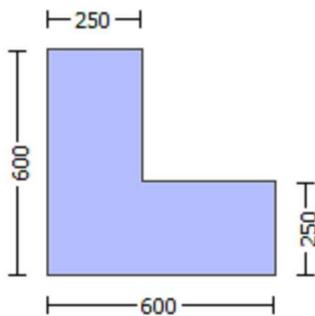
Calculation of ratio l_b/d

Lap Length: $l_d/l_d, \text{min} = 0.33351241$
 $l_b = 300.00$
 $l_d = 899.5167$
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 = 1.03342
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
s = 380.00
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 (θ)
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, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length l_o = 300.00
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, f_{fu} = 1055.00
Tensile Modulus, E_f = 64828.00
Elongation, e_{fu} = 0.01
Number of directions, 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_{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

Calculation of Shear Capacity ratio, V_e/V_r = 0.60501747
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$
with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.8119\text{E}+008$
 $\mu_{1+} = 3.8119\text{E}+008$, 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
 $\mu_{1-} = 2.0589\text{E}+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.8119\text{E}+008$
 $\mu_{2+} = 3.8119\text{E}+008$, 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
 $\mu_{2-} = 2.0589\text{E}+008$, 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 μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 1.0933130\text{E}-005$
 $\mu = 3.8119\text{E}+008$

with full section properties:
 $b = 250.00$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$$

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

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

$A_{conf,min} = 3525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

$c = \text{confinement factor} = 1.0981$
 $y1 = 0.0011992$
 $sh1 = 0.00414446$
 $ft1 = 345.3682$
 $fy1 = 287.8069$
 $su1 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.26680993$
 $su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fs1 = fs = 287.8069$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0011992$
 $sh2 = 0.00414446$
 $ft2 = 345.3682$
 $fy2 = 287.8069$
 $su2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 0.26680993$
 $su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fs2 = fs = 287.8069$
 with $Es2 = Es = 200000.00$
 $yv = 0.0011992$
 $shv = 0.00414446$
 $ftv = 345.3682$
 $fyv = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.26680993$
 $suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fsv = fs = 287.8069$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.18050973$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.08570966$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.15973163$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 21.96205$
 $cc (5A.5, \text{TBDY}) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.25103346$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.11919574$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.22213752$
 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) = 0.31943706
Mu = MRc (4.15) = 3.8119E+008
u = su (4.1) = 1.0933130E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.26680993

lb = 300.00

l_d = 1124.396

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 1.03342

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 = 380.00

n = 16.00

Calculation of Mu1-

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

u = 9.0418593E-006

Mu = 2.0589E+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) = 0.014005

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.014005

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.0689719

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)^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

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

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

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00781147$
The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00127056$

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)

$psh_x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$psh_y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

s = 380.00
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

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

$y_1 = 0.0011992$
 $sh_1 = 0.00414446$
 $ft_1 = 345.3682$
 $fy_1 = 287.8069$
 $su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{,min} = lb/l_d = 0.26680993$

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

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 $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{,min} = lb/l_{b,min} = 0.26680993$

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

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

with $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$s_{uv} = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lo_{u,min} = lb/d = 0.26680993$

$s_{uv} = 0.4 \cdot es_{uv_nominal}$ ((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 $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_v = fs = 287.8069$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.03571236$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.07521239$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.06655485$

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 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.04193924$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.08832659$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.0781595$

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) = 0.17708486

$\mu_u = MR_c$ (4.14) = 2.0589E+008

$u = s_u$ (4.1) = 9.0418593E-006

Calculation of ratio lb/d

Lap Length: $lb/d = 0.26680993$

$lb = 300.00$

$ld = 1124.396$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.03342$

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

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

$s = 380.00$

$n = 16.00$

Calculation of Mu2+

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

$$\mu = 1.0933130E-005$$

$$Mu = 3.8119E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e^* s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

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

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00127056

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 380.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.0981

y1 = 0.0011992

sh1 = 0.00414446

ft1 = 345.3682

fy1 = 287.8069

su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es1 = Es = 200000.00

y2 = 0.0011992

sh2 = 0.00414446

ft2 = 345.3682

fy2 = 287.8069

su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es2 = Es = 200000.00

yv = 0.0011992

shv = 0.00414446

ftv = 345.3682

fyv = 287.8069

suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.18050973

2 = Asl,com/(b*d)*(fs2/fc) = 0.08570966

v = Asl,mid/(b*d)*(fsv/fc) = 0.15973163

and confined core properties:

b = 190.00

d = 527.00

$d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.25103346$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11919574$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.22213752$
 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
 --->
 $su (4.8) = 0.31943706$
 $Mu = MRc (4.15) = 3.8119E+008$
 $u = su (4.1) = 1.0933130E-005$

 Calculation of ratio l_b/l_d

 Lap Length: $l_b/l_d = 0.26680993$
 $l_b = 300.00$
 $l_d = 1124.396$
 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)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.03342$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis
 $s = 380.00$
 $n = 16.00$

 Calculation of Mu_2 -

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 9.0418593E-006$
 $Mu = 2.0589E+008$

 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 : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.014005$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.014005$
 $w_e ((5.4c), TBDY) = a_s * sh, \min * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$
 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, $tf = NL*t*\text{Cos}(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase = $\text{Max}(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.00781147$
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 = 3525.00 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 = $\text{Min}(psh,x, psh,y) = 0.00127056$
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) = $Lstir * Astir / (Asec * s) = 0.00127056$
Lstir (Length of stirrups along Y) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00127056$
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 380.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
c = confinement factor = 1.0981
y1 = 0.0011992
sh1 = 0.00414446
ft1 = 345.3682
fy1 = 287.8069
su1 = 0.00414446
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
lo/lou,min = $lb/d = 0.26680993$
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 $fs1 = fs = 287.8069$

with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_0/l_{ou,min} = l_b/l_{b,min} = 0.26680993$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = fs = 287.8069$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $fy_v = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_0/l_{ou,min} = l_b/l_d = 0.26680993$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 287.8069$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.03571236$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.07521239$
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.06655485$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.04193924$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.08832659$
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.0781595$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_s, y_2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17708486$
 $Mu = MRc (4.14) = 2.0589E+008$
 $u = su (4.1) = 9.0418593E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$
 $l_b = 300.00$
 $l_d = 1124.396$
 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)

$t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 1.03342$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis
 $s = 380.00$
 $n = 16.00$

 Calculation of Shear Strength $Vr = \text{Min}(Vr1, Vr2) = 420034.424$

Calculation of Shear Strength at edge 1, $Vr1 = 420034.424$
 $Vr1 = VCol$ ((10.3), ASCE 41-17) = $knl * VCol0$
 $VCol0 = 420034.424$
 $knl = 1$ (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: $Vs = Vs1 + Vs2 = 73486.813$

where:

$Vs1 = 73486.813$ is calculated for section web, with:
 $d = 480.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 380.00$

$Vs1$ is multiplied by $Col1 = 0.83333333$
 $s/d = 0.79166667$

$Vs2 = 0.00$ is calculated for section flange, with:
 $d = 200.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 380.00$

$Vs2$ is multiplied by $Col2 = 0.00$
 $s/d = 1.90$

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 α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $Vf(\alpha, ai)$, 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: $\alpha = b1 + 90^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, 1)|, |Vf(-45, a1)|)$, 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, $Vr2 = 420034.424$

$Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl * VCol0$
 $VCol0 = 420034.424$
 $knl = 1$ (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: $Vs = Vs1 + Vs2 = 73486.813$

where:

$Vs1 = 73486.813$ is calculated for section web, with:

$d = 480.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 380.00$

$Vs1$ is multiplied by $Col1 = 0.83333333$

$s/d = 0.79166667$

$Vs2 = 0.00$ is calculated for section flange, with:

$d = 200.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 380.00$

$Vs2$ is multiplied by $Col2 = 0.00$

$s/d = 1.90$

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, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $a1 = b1 + 90^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, a1)|, |Vf(-45, a1)|)$, 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: $Vs + Vf \leq 356502.845$

$bw = 250.00$

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, $\gamma = 1.00$

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

Consequently:

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

```

Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 444.44$ 
Concrete Elasticity,  $E_c = 21019.039$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
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,  $L = 3000.00$ 
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length  $l_o = 300.00$ 
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $N_{oDir} = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $N_L = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
At local axis: 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,  $V_e/V_r = 0.60501747$ 
Member Controlled by Flexure ( $V_e/V_r < 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$ 
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.8119E+008$ 
 $M_{u1+} = 3.8119E+008$ , 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
 $M_{u1-} = 2.0589E+008$ , 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.8119E+008$ 
 $M_{u2+} = 3.8119E+008$ , 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
 $M_{u2-} = 2.0589E+008$ , 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 μ_{1+}

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

$$u = 1.0933130E-005$$

$$\mu_u = 3.8119E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$$

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

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

$A_{conf,min} = 3525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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) = 0.00127056
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 380.00
fywe = 555.55
fce = 20.00

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

y1 = 0.0011992
sh1 = 0.00414446
ft1 = 345.3682
fy1 = 287.8069
su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es1 = Es = 200000.00

y2 = 0.0011992
sh2 = 0.00414446
ft2 = 345.3682
fy2 = 287.8069
su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es2 = Es = 200000.00

yv = 0.0011992
shv = 0.00414446
ftv = 345.3682
fyv = 287.8069
suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.18050973

2 = Asl,com/(b*d)*(fs2/fc) = 0.08570966

v = Asl,mid/(b*d)*(fsv/fc) = 0.15973163

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.25103346$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11919574$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.22213752$
 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

--->
 $su (4.8) = 0.31943706$
 $Mu = MRc (4.15) = 3.8119E+008$
 $u = su (4.1) = 1.0933130E-005$

 Calculation of ratio l_b/d

 Lap Length: $l_b/d = 0.26680993$

$l_b = 300.00$
 $l_d = 1124.396$

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)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.03342$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = 380.00$
 $n = 16.00$

 Calculation of $Mu1$ -

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

$u = 9.0418593E-006$
 $Mu = 2.0589E+008$

 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 : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.014005$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.014005$
 $we ((5.4c), TBDY) = ase * sh, \min * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$
 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 = $\text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}), 0) = 0.00781147$
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 = 3525.00 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 = $\text{Min}(psh,x, psh,y) = 0.00127056$
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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
Lstir (Length of stirrups along Y) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 380.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00298102
c = confinement factor = 1.0981
y1 = 0.0011992
sh1 = 0.00414446
ft1 = 345.3682
fy1 = 287.8069
su1 = 0.00414446
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
lo/lou,min = $l_b/l_d = 0.26680993$
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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$

$sh_2 = 0.00414446$

$ft_2 = 345.3682$

$fy_2 = 287.8069$

$su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.26680993$

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

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 $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$suv = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.26680993$

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

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

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

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

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

with $fsv = fs = 287.8069$

with $Es_v = Es = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.03571236$

$2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.07521239$

$v = A_{sl,mid}/(b \cdot d) \cdot (fsv/f_c) = 0.06655485$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

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

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

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

$1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.04193924$

$2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.08832659$

$v = A_{sl,mid}/(b \cdot d) \cdot (fsv/f_c) = 0.0781595$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.17708486$

$Mu = MRc (4.14) = 2.0589E+008$

$u = su (4.1) = 9.0418593E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$l_b = 300.00$

$l_d = 1124.396$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.03342$

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

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

$s = 380.00$

$n = 16.00$

Calculation of μ_{2+}

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

$\mu = 1.0933130E-005$

$M_u = 3.8119E+008$

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 μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_s) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.014005$

where ((5.4c), TBDY) = $\alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

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), $f_{fe} = 703.4155$

 $f_y = 0.06888919$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$

The definitions of A_{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.

$A_{conf,min} = 3525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y_1 = 0.0011992$

$sh_1 = 0.00414446$

$ft_1 = 345.3682$

$fy_1 = 287.8069$

$su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.26680993$

$su_1 = 0.4 * esu_{1,nominal}$ ((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 $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$

$sh_2 = 0.00414446$

$ft_2 = 345.3682$

$fy_2 = 287.8069$

$su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.26680993$

$su_2 = 0.4 * esu_{2,nominal}$ ((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 $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$su_v = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.26680993$

$su_v = 0.4 * esu_{v,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsv = fsv/1.2$, 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 $fsv = fs = 287.8069$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.18050973$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.08570966$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.15973163$

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
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.25103346$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.11919574$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.22213752$

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) = 0.31943706
 $Mu = MRc$ (4.15) = 3.8119E+008
 $u = su$ (4.1) = 1.0933130E-005

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.26680993$

$lb = 300.00$
 $ld = 1124.396$

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 $fc'^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 1.03342$
 $Atr = Min(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 380.00$
 $n = 16.00$

 Calculation of $Mu2$ -

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

$u = 9.0418593E-006$
 $Mu = 2.0589E+008$

 with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0011992$$

$$sh_1 = 0.00414446$$

$$ft1 = 345.3682$$

$$fy1 = 287.8069$$

$$su1 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/l_d = 0.26680993$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

$$\text{with } fs1 = fs = 287.8069$$

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

$$y2 = 0.0011992$$

$$sh2 = 0.00414446$$

$$ft2 = 345.3682$$

$$fy2 = 287.8069$$

$$su2 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/l_b,min = 0.26680993$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

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

$$\text{with } fs2 = fs = 287.8069$$

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

$$yv = 0.0011992$$

$$shv = 0.00414446$$

$$ftv = 345.3682$$

$$fyv = 287.8069$$

$$suv = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/l_d = 0.26680993$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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

$$\text{with } fsv = fs = 287.8069$$

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.03571236$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.07521239$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.06655485$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

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

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

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.04193924$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.08832659$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.0781595$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.17708486$$

$$Mu = MRc (4.14) = 2.0589E+008$$

$$u = s_u(4.1) = 9.0418593E-006$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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: $f_y = 555.55$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 420034.424$

Calculation of Shear Strength at edge 1, $V_{r1} = 420034.424$

$$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$$

$$V_{Col0} = 420034.424$$

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

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).

$$= 1 \text{ (normal-weight concrete)}$$

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

$$M/Vd = 4.00$$

$$M_u = 47.23669$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 73486.813$$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s1} is multiplied by $Col1 = 0.00$

$$s/d = 1.90$$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s2} is multiplied by $Col2 = 0.83333333$

$$s/d = 0.79166667$$

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

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

$w_f/s_f = 1$ (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 α 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 α_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: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (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, $V_{r2} = 420034.424$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 420034.424$
 $k_{nl} = 1$ (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: $V_s = V_{s1} + V_{s2} = 73486.813$
where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.90$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

V_{s2} is multiplied by $Col2 = 0.83333333$

$s/d = 0.79166667$

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 θ 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 α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (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, $\gamma = 1.00$

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 600.00$

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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 108099.704$

Shear Force, $V_2 = 2806.138$

Shear Force, $V_3 = -97.69573$

Axial Force, $F = -9396.789$

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: $A_{sl,com} = 829.3805$

-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 $u_{,R} = \gamma \cdot u = 0.00067292$

$u = \gamma \cdot u_p = 0.00067292$

- Calculation of γ -

$\gamma = (M_y \cdot L_s / 3) / E_{eff} = 0.00067292 ((4.29), \text{Biskinis Phd})$

$M_y = 2.8210E+008$
 $L_s = M/V$ (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 = 9396.789
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.8954822E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 267.1762$
d = 557.00
y = 0.38432516
A = 0.02985235
B = 0.0192346
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9396.789
b = 250.00
" = 0.07719928
 $y_{comp} = 8.1953653E-006$
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 = 0.38315844
A = 0.02940687
B = 0.01898202
with Es = 200000.00

Calculation of ratio I_b / I_d

Lap Length: $I_d / I_d, \text{min} = 0.33351241$
lb = 300.00
ld = 899.5167
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 = 1.03342
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

s = 380.00
n = 16.00

- Calculation of ρ -

From table 10-8: $\rho = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_y E / V_{CoI} E = 0.60501747$

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.

$N_{UD} = 9396.789$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02959978$

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

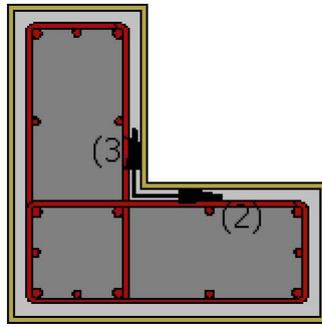
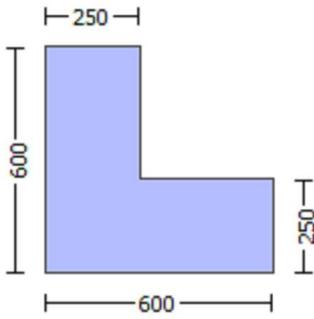
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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, $\gamma = 1.00$

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 Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ 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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

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

Shear Force, $V_a = -4259.045$

EDGE -B-

Bending Moment, $M_b = 164093.875$

Shear Force, $V_b = 4259.045$

BOTH EDGES

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: $A_{st,mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 379611.735$

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

$V_{CoI} = 379611.735$

$k_n = 1.00$

$displacement_ductility_demand = 0.01858259$

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)

$M/Vd = 4.00$

$\mu_u = 1.2946E+007$

$V_u = 4259.045$

$d = 0.8 \cdot h = 480.00$

$N_u = 9662.362$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 66138.793$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 380.00$

V_{s1} is multiplied by $\phi_{Col1} = 0.00$

$s/d = 1.90$

$V_{s2} = 66138.793$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 380.00$

V_{s2} is multiplied by $\phi_{Col2} = 0.83333333$

$s/d = 0.79166667$

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 θ 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 α_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 δ / y

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

From analysis, chord rotation $\theta = 0.00012672$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00681915$ ((4.29), Biskinis Phd)
 $M_y = 2.8215E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3039.546
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9662.362$
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.8958781E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 267.1762$
 $d = 557.00$
 $y = 0.38438772$
 $A = 0.02985949$
 $B = 0.01924174$
with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9662.362$
 $b = 250.00$
 $t = 0.07719928$
 $y_{comp} = 8.1947240E-006$
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), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38318842$
 $A = 0.02940142$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio l_b / l_d

Lap Length: $l_d / l_d, \text{min} = 0.33351241$
 $l_b = 300.00$
 $l_d = 899.5167$

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

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 = 1.03342

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

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

s = 380.00

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

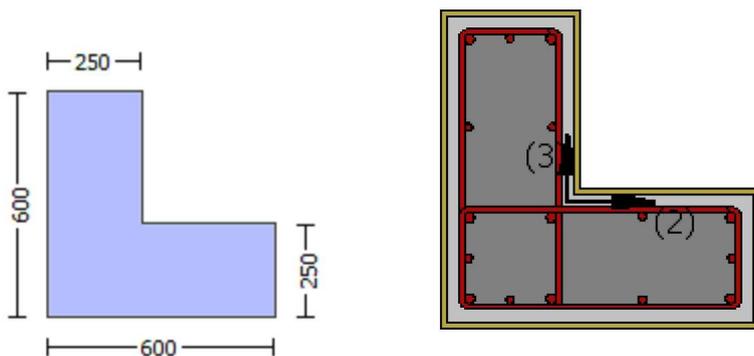
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

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, = 1.00

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
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, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 0.00016213$
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, $V_e/V_r = 0.60501747$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.8119E+008$
 $M_{u1+} = 3.8119E+008$, 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
 $M_{u1-} = 2.0589E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.8119E+008$
 $M_{u2+} = 3.8119E+008$, 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
 $M_{u2-} = 2.0589E+008$, 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 μ_{1+}

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

$$u = 1.0933130E-005$$

$$\mu = 3.8119E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$$

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

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

$A_{conf,min} = 3525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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) = 0.00127056
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 380.00
fywe = 555.55
fce = 20.00

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

y1 = 0.0011992
sh1 = 0.00414446
ft1 = 345.3682
fy1 = 287.8069
su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069
with Es1 = Es = 200000.00

y2 = 0.0011992
sh2 = 0.00414446
ft2 = 345.3682
fy2 = 287.8069
su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069
with Es2 = Es = 200000.00

yv = 0.0011992
shv = 0.00414446
ftv = 345.3682
fyv = 287.8069
suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069
with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.18050973
2 = Asl,com/(b*d)*(fs2/fc) = 0.08570966
v = Asl,mid/(b*d)*(fsv/fc) = 0.15973163

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.25103346$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11919574$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.22213752$
 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

--->
 $su (4.8) = 0.31943706$
 $Mu = MRc (4.15) = 3.8119E+008$
 $u = su (4.1) = 1.0933130E-005$

 Calculation of ratio l_b/d

 Lap Length: $l_b/d = 0.26680993$

$l_b = 300.00$
 $l_d = 1124.396$

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)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.03342$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 380.00$
 $n = 16.00$

 Calculation of $Mu1$ -

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

$u = 9.0418593E-006$
 $Mu = 2.0589E+008$

 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 : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.014005$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.014005$
 $we ((5.4c), TBDY) = ase * sh, \min * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$
 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 = $NL*t*\text{Cos}(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase = $\text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.00781147$
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 = 3525.00 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 = $\text{Min}(psh,x, psh,y) = 0.00127056$
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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
Lstir (Length of stirrups along Y) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 380.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00298102
c = confinement factor = 1.0981
y1 = 0.0011992
sh1 = 0.00414446
ft1 = 345.3682
fy1 = 287.8069
su1 = 0.00414446
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
lo/lou,min = $l_b/l_d = 0.26680993$
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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$

$sh_2 = 0.00414446$

$ft_2 = 345.3682$

$fy_2 = 287.8069$

$su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.26680993$

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

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

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

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

with $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$su_v = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.26680993$

$su_v = 0.4 \cdot esu_{v,nominal} ((5.5), \text{TBDY}) = 0.032$

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

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

For calculation of $esu_{v,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $fsy_v = fs_v/1.2$, from table 5.1, TBDY.

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

with $fs_v = fs = 287.8069$

with $Es_v = Es = 200000.00$

$1 = A_{s1,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.03571236$

$2 = A_{s1,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.07521239$

$v = A_{s1,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.06655485$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

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

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

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

$1 = A_{s1,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.04193924$

$2 = A_{s1,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.08832659$

$v = A_{s1,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.0781595$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$su (4.9) = 0.17708486$

$Mu = MRc (4.14) = 2.0589E+008$

$u = su (4.1) = 9.0418593E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$l_b = 300.00$

$l_d = 1124.396$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.03342$

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

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

$s = 380.00$

$n = 16.00$

Calculation of μ_{2+}

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

$\mu = 1.0933130E-005$

$M_u = 3.8119E+008$

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 μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.014005$

where ((5.4c), TBDY) = $\alpha s e^* s h_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

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), $f_{fe} = 703.4155$

 $f_y = 0.06888919$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$

The definitions of A_{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 = 3525.00 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) = 0.00127056

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) = 0.00127056

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) = 0.00127056

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 380.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.0981

y1 = 0.0011992

sh1 = 0.00414446

ft1 = 345.3682

fy1 = 287.8069

su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es1 = Es = 200000.00

y2 = 0.0011992

sh2 = 0.00414446

ft2 = 345.3682

fy2 = 287.8069

su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es2 = Es = 200000.00

yv = 0.0011992

shv = 0.00414446

ftv = 345.3682

fyv = 287.8069

suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esuv_nominal = 0.08$,
considering characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
characteristic value $fsv = fsv/1.2$, 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 $fsv = fs = 287.8069$
with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.18050973$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.08570966$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.15973163$

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
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.25103346$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.11919574$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.22213752$

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) = 0.31943706
 $Mu = MRc$ (4.15) = 3.8119E+008
 $u = su$ (4.1) = 1.0933130E-005

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$

$lb = 300.00$
 $ld = 1124.396$

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 $fc'^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 1.03342$
 $Atr = Min(Atr_x, Atr_y) = 157.0796$
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 380.00$
 $n = 16.00$

Calculation of $Mu2$ -

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

$u = 9.0418593E-006$
 $Mu = 2.0589E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.0011992$$

$$sh_1 = 0.00414446$$

$ft1 = 345.3682$
 $fy1 = 287.8069$
 $su1 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.26680993$
 $su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$
 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 $fs1 = fs = 287.8069$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0011992$
 $sh2 = 0.00414446$
 $ft2 = 345.3682$
 $fy2 = 287.8069$
 $su2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.26680993$
 $su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$
 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 $fs2 = fs = 287.8069$
 with $Es2 = Es = 200000.00$
 $yv = 0.0011992$
 $shv = 0.00414446$
 $ftv = 345.3682$
 $fyv = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.26680993$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 287.8069$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.03571236$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.07521239$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.06655485$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.04193924$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.08832659$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.0781595$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17708486$
 $Mu = MRc (4.14) = 2.0589E+008$

$$u = s_u(4.1) = 9.0418593E-006$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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: $f_y = 555.55$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 420034.424$

Calculation of Shear Strength at edge 1, $V_{r1} = 420034.424$

$$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$$

$$V_{Col0} = 420034.424$$

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

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).

$$= 1 \text{ (normal-weight concrete)}$$

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

$$M/Vd = 4.00$$

$$M_u = 47.24078$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 73486.813$$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s1} is multiplied by $Col1 = 0.83333333$

$$s/d = 0.79166667$$

$V_{s2} = 0.00$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s2} is multiplied by $Col2 = 0.00$

$$s/d = 1.90$$

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

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

$w_f/s_f = 1$ (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 a 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 α_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: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 420034.424$
 $V_{r2} = V_{CoI}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{CoI0}$
 $V_{CoI0} = 420034.424$
 $k_{nl} = 1$ (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: $V_s = V_{s1} + V_{s2} = 73486.813$
where:

$V_{s1} = 73486.813$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

V_{s1} is multiplied by $Col1 = 0.83333333$
 $s/d = 0.79166667$

$V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.90$

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 θ 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: 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, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = 0.00016213$

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 , $V_e/V_r = 0.60501747$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$

with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.8119\text{E}+008$
 $\mu_{1+} = 3.8119\text{E}+008$, 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
 $\mu_{1-} = 2.0589\text{E}+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.8119\text{E}+008$
 $\mu_{2+} = 3.8119\text{E}+008$, 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
 $\mu_{2-} = 2.0589\text{E}+008$, 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 μ_{1+}

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

$\mu = 1.0933130\text{E}-005$

$\mu = 3.8119\text{E}+008$

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 μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_s) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.014005$

$\mu_s ((5.4c), \text{TBDY}) = \alpha * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00781147$

The definitions of A_{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.
 $A_{conf,min} = 3525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

$c =$ confinement factor = 1.0981

$y_1 = 0.0011992$

$sh_1 = 0.00414446$

$ft_1 = 345.3682$

$fy_1 = 287.8069$

$su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.26680993$

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

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 $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$

$sh_2 = 0.00414446$

$ft_2 = 345.3682$

$fy_2 = 287.8069$

$su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.26680993$

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

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 $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$su_v = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.26680993$$

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

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 γ_v , sh_v, ft_v, fy_v , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_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.

$$\text{with } f_{sv} = f_s = 287.8069$$

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.18050973$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.08570966$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.15973163$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.25103346$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.11919574$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.22213752$$

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

---->

$$s_u (4.8) = 0.31943706$$

$$M_u = M_{Rc} (4.15) = 3.8119E+008$$

$$u = s_u (4.1) = 1.0933130E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of M_u1-

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

$$u = 9.0418593E-006$$

$$M_u = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$$

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

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

$A_{conf,min} = 3525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$y_1 = 0.0011992$
 $sh_1 = 0.00414446$
 $ft_1 = 345.3682$
 $fy_1 = 287.8069$
 $su_1 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.26680993$
 $su_1 = 0.4*esu_1,nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_1,nominal = 0.08$,
 For calculation of $esu_1,nominal$ and y_1, sh_1,ft_1,fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1,ft_1,fy_1 , are also multiplied by $Min(1,1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 287.8069$
 with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.26680993$
 $su_2 = 0.4*esu_2,nominal ((5.5), TBDY) = 0.032$
 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 $fs_2 = fs = 287.8069$
 with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $fy_v = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.26680993$
 $suv = 0.4*esuv,nominal ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 287.8069$
 with $Esv = Es = 200000.00$

$1 = Asl,ten/(b*d)*(fs_1/fc) = 0.03571236$
 $2 = Asl,com/(b*d)*(fs_2/fc) = 0.07521239$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.06655485$

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl,ten/(b*d)*(fs_1/fc) = 0.04193924$
 $2 = Asl,com/(b*d)*(fs_2/fc) = 0.08832659$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.0781595$

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

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

su (4.9) = 0.17708486
Mu = MRc (4.14) = 2.0589E+008
u = su (4.1) = 9.0418593E-006

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.26680993

lb = 300.00

l_d = 1124.396

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} ≤ 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 1.03342

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 loxal axis

s = 380.00

n = 16.00

Calculation of Mu₂₊

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

u = 1.0933130E-005

Mu = 3.8119E+008

with full section properties:

b = 250.00

d = 557.00

d' = 43.00

v = 0.0031899

N = 8883.864

f_c' = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.014005

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.014005

w_e ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(f_x, f_y) = 0.0689719

where f = af*pf*ffe/fce 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 - (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_y = 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.4.4.3(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, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$

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

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

$A_{conf,min} = 3525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

c = confinement factor = 1.0981

$y_1 = 0.0011992$

$sh_1 = 0.00414446$

$ft_1 = 345.3682$

$fy_1 = 287.8069$

$su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.26680993$

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

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 $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$

$sh_2 = 0.00414446$

$ft_2 = 345.3682$

$fy_2 = 287.8069$

$su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.26680993$

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

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 $fs2 = fs = 287.8069$

with $Es2 = Es = 200000.00$

$yv = 0.0011992$

$shv = 0.00414446$

$ftv = 345.3682$

$fyv = 287.8069$

$suv = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.26680993$

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

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 $fsv = fs = 287.8069$

with $Es = Es = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.18050973$

2 = $Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.08570966$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.15973163$

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 = $Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.25103346$

2 = $Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.11919574$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.22213752$

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

--->

$su (4.8) = 0.31943706$

$Mu = MRc (4.15) = 3.8119E+008$

u = $su (4.1) = 1.0933130E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$

$lb = 300.00$

$ld = 1124.396$

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

$cb = 25.00$

$K_{tr} = 1.03342$

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

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

s = 380.00

n = 16.00

Calculation of Mu2-

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

$$u = 9.0418593E-006$$

$$Mu = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e(5.4c, TBDY) = a_s e^* s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x}(5.4d, TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

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

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

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

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00127056

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 380.00

fywe = 555.55

fce = 20.00

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

c = confinement factor = 1.0981

y1 = 0.0011992

sh1 = 0.00414446

ft1 = 345.3682

fy1 = 287.8069

su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es1 = Es = 200000.00

y2 = 0.0011992

sh2 = 0.00414446

ft2 = 345.3682

fy2 = 287.8069

su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es2 = Es = 200000.00

yv = 0.0011992

shv = 0.00414446

ftv = 345.3682

fyv = 287.8069

suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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

with fsv = fs = 287.8069

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03571236

2 = Asl,com/(b*d)*(fs2/fc) = 0.07521239

v = Asl,mid/(b*d)*(fsv/fc) = 0.06655485

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
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04193924$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08832659$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0781595$
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

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

--->
 μ_u (4.9) = 0.17708486
 $M_u = MR_c$ (4.14) = 2.0589E+008
 $u = \mu_u$ (4.1) = 9.0418593E-006

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$l_b = 300.00$

$l_d = 1124.396$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.03342$

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

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

$s = 380.00$

$n = 16.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 420034.424$

Calculation of Shear Strength at edge 1, $V_{r1} = 420034.424$

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

$V_{Col0} = 420034.424$

$k_{nl} = 1$ (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: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.90$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$
 V_{s2} is multiplied by $Col2 = 0.83333333$
 $s/d = 0.79166667$
 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 θ 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: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, 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, $V_{r2} = 420034.424$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{Col0}$
 $V_{Col0} = 420034.424$
 $k_n l = 1$ (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)
 $M/Vd = 4.00$
 $\mu_u = 47.23667$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 73486.813$
 where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.90$
 $V_{s2} = 73486.813$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$
 V_{s2} is multiplied by $Col2 = 0.83333333$
 $s/d = 0.79166667$
 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 θ 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: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, 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: 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, = 1.00
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 Primary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Primary 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
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length 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 = -320830.405
Shear Force, V2 = -4259.045
Shear Force, V3 = 148.2786
Axial Force, F = -9662.362
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 $u_{R} = u = 0.04685421$
 $u = y + p = 0.04685421$

- Calculation of y -

$y = (My * Ls / 3) / Eleff = 0.00485421$ ((4.29), Biskinis Phd))
 $My = 2.8215E+008$
 $Ls = M/V$ (with $Ls > 0.1 * L$ and $Ls < 2 * L$) = 2163.70
From table 10.5, ASCE 41_17: $Eleff = factor * Ec * Ig = 4.1921E+013$
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 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.8958781E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (lb/d)^{2/3}) = 267.1762$
 $d = 557.00$
 $y = 0.38438772$
 $A = 0.02985949$
 $B = 0.01924174$
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), $e_{fe} = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 21019.039$
 $y = 0.38318842$
 $A = 0.02940142$
 $B = 0.01898202$
with $Es = 200000.00$

Calculation of ratio lb/d

Lap Length: $ld/ld_{min} = 0.33351241$
 $lb = 300.00$

$$l_d = 899.5167$$

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: $f_y = 444.44$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

- Calculation of p -

From table 10-8: $p = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$

$$\text{shear control ratio } V_y E / V_{col} E = 0.60501747$$

$$d = 557.00$$

$$s = 0.00$$

$$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$$

$A_v = 78.53982$, 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.

$$N_{UD} = 9662.362$$

$$A_g = 237500.00$$

$$f'_c E = 20.00$$

$$f_{yt} E = f_{yl} E = 0.00$$

$$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02959978$$

$$b = 250.00$$

$$d = 557.00$$

$$f'_c E = 20.00$$

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

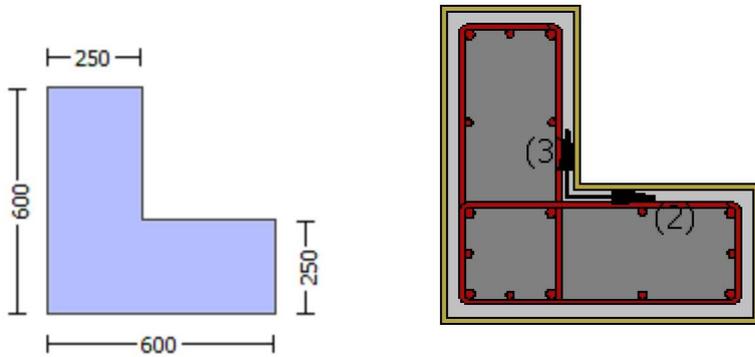
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

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, $\gamma = 1.00$

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 Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ 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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $Ma = -320830.405$
Shear Force, $Va = 148.2786$
EDGE -B-
Bending Moment, $Mb = -122390.947$
Shear Force, $Vb = -148.2786$
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 $VR = *V_n = 379611.735$
 $V_n ((10.3), ASCE 41-17) = knl * V_{Co10} = 379611.735$
 $V_{Co1} = 379611.735$
 $knl = 1.00$
 $displacement_ductility_demand = 0.00977699$

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)
 $fc' = 16.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 320830.405$
 $V_u = 148.2786$
 $d = 0.8 * h = 480.00$
 $N_u = 9662.362$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 66138.793$
where:
 $V_{s1} = 66138.793$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
 V_{s1} is multiplied by $Col1 = 0.83333333$
 $s/d = 0.79166667$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.90$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, 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 θ is the angle of the crack direction (see KANEPE).

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

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

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

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

$d_{fv} = d$ (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 δ / y

- Calculation of δ / y for END A -

for rotation axis 2 and integ. section (a)

From analysis, chord rotation $\theta = 4.7459577E-005$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00485421$ ((4.29), Biskinis Phd)

$M_y = 2.8215E+008$

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

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

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 δ / y and M_y according to Annex 7 -

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

$y_{\text{ten}} = 3.8958781E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 267.1762$

$d = 557.00$

$y = 0.38438772$

$A = 0.02985949$

$B = 0.01924174$

with $p_t = 0.01254381$

$p_c = 0.00595605$

$p_v = 0.01109992$

$N = 9662.362$

$b = 250.00$

$\alpha = 0.07719928$

$y_{\text{comp}} = 8.1947240E-006$

with f_c^* (12.3, (ACI 440)) = 20.42407

$f_c = 20.00$

$f_l = 0.62098351$

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

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

$A_g = 237500.00$

$g = p_t + p_c + p_v = 0.02959978$

$r_c = 40.00$

$A_e / A_c = 0.21783041$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.38318842$

A = 0.02940142
B = 0.01898202
with $E_s = 200000.00$

Calculation of ratio l_b/d

Lap Length: $l_d/d, \min = 0.33351241$

$l_b = 300.00$

$l_d = 899.5167$

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

$\beta = 1$

$d_b = 18.00$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.03342$

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

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

$s = 380.00$

$n = 16.00$

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

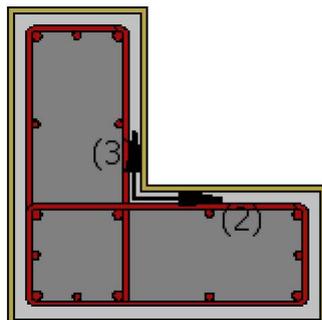
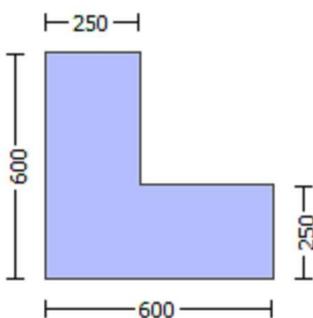
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_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, $k = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

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: $As_{l,ten} = 1746.726$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.60501747$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$

with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.8119\text{E}+008$
 $\mu_{1+} = 3.8119\text{E}+008$, 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
 $\mu_{1-} = 2.0589\text{E}+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.8119\text{E}+008$
 $\mu_{2+} = 3.8119\text{E}+008$, 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
 $\mu_{2-} = 2.0589\text{E}+008$, 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 μ_{1+}

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

$\mu = 1.0933130\text{E}-005$

$\mu_u = 3.8119\text{E}+008$

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 μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_u = 0.014005$

μ_{ve} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{\min} * f_{yve}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

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

$b_{\max} = 600.00$

$h_{\max} = 600.00$

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

$b_w = 250.00$

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

$f_y = 0.06888919$

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), $\rho_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,1} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00781147$

The definitions of A_{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.
 $A_{conf,min} = 3525.00$ is 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).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00127056$

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)

$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y_1 = 0.0011992$

$sh_1 = 0.00414446$

$ft_1 = 345.3682$

$fy_1 = 287.8069$

$su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.26680993$

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

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 $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$

$sh_2 = 0.00414446$

$ft_2 = 345.3682$

$fy_2 = 287.8069$

$su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.26680993$

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

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 $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$su_v = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.26680993$$

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

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 γ_v , sh_v, ft_v, fy_v , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_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.

$$\text{with } f_{sv} = f_s = 287.8069$$

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.18050973$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.08570966$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.15973163$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.25103346$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.11919574$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.22213752$$

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

---->

$$s_u (4.8) = 0.31943706$$

$$M_u = M_{Rc} (4.15) = 3.8119E+008$$

$$u = s_u (4.1) = 1.0933130E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

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

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

$$s = 380.00$$

$$n = 16.00$$

Calculation of M_u1-

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

$$u = 9.0418593E-006$$

$$M_u = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e(5.4c, TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00781147$$

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

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

$A_{conf,min} = 3525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

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

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

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

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$y_1 = 0.0011992$
 $sh_1 = 0.00414446$
 $ft_1 = 345.3682$
 $fy_1 = 287.8069$
 $su_1 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/d = 0.26680993$
 $su_1 = 0.4 * esu_1,nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_1,nominal = 0.08$,
 For calculation of $esu_1,nominal$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 287.8069$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.26680993$
 $su_2 = 0.4 * esu_2,nominal ((5.5), TBDY) = 0.032$
 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 $Min(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 287.8069$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $fy_v = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/d = 0.26680993$
 $suv = 0.4 * esuv,nominal ((5.5), TBDY) = 0.032$
 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 $Min(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 287.8069$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.03571236$
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.07521239$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.06655485$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.04193924$
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.08832659$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.0781595$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

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

su (4.9) = 0.17708486
Mu = MRc (4.14) = 2.0589E+008
u = su (4.1) = 9.0418593E-006

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.26680993

lb = 300.00

l_d = 1124.396

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} ≤ 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 1.03342

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 loxal axis

s = 380.00

n = 16.00

Calculation of Mu₂₊

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

u = 1.0933130E-005

Mu = 3.8119E+008

with full section properties:

b = 250.00

d = 557.00

d' = 43.00

v = 0.0031899

N = 8883.864

f_c' = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.014005

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.014005

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.0689719

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)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

fy = 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.4.4.3(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, $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$

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

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

$A_{conf,min} = 3525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

c = confinement factor = 1.0981

$y_1 = 0.0011992$

$sh_1 = 0.00414446$

$ft_1 = 345.3682$

$fy_1 = 287.8069$

$su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.26680993$

$su_1 = 0.4 * esu_{1,nominal}$ ((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 $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$

$sh_2 = 0.00414446$

$ft_2 = 345.3682$

$fy_2 = 287.8069$

$su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.26680993$

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

with $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$suv = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.26680993$

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

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

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

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

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

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

with $fsv = fs = 287.8069$

with $Es_v = Es = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.18050973$

2 = $Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.08570966$

$v = Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.15973163$

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 = $Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.25103346$

2 = $Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.11919574$

$v = Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.22213752$

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

--->

$su (4.8) = 0.31943706$

$Mu = MRc (4.15) = 3.8119E+008$

$u = su (4.1) = 1.0933130E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$

$lb = 300.00$

$ld = 1124.396$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.03342$

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

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

$s = 380.00$

$n = 16.00$

Calculation of Mu2-

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

$$\mu = 9.0418593E-006$$

$$Mu = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e^* \text{ sh, min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

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

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

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

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

$$b_w = 250.00$$

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

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,\text{min}} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00127056

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 380.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.0011992

sh1 = 0.00414446

ft1 = 345.3682

fy1 = 287.8069

su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es1 = Es = 200000.00

y2 = 0.0011992

sh2 = 0.00414446

ft2 = 345.3682

fy2 = 287.8069

su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es2 = Es = 200000.00

yv = 0.0011992

shv = 0.00414446

ftv = 345.3682

fyv = 287.8069

suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03571236

2 = Asl,com/(b*d)*(fs2/fc) = 0.07521239

v = Asl,mid/(b*d)*(fsv/fc) = 0.06655485

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

$$f_{cc} \text{ (5A.2, TBDY)} = 21.96205$$

$$c_c \text{ (5A.5, TBDY)} = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04193924$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08832659$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0781595$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$\mu_u \text{ (4.9)} = 0.17708486$$

$$M_u = M_{Rc} \text{ (4.14)} = 2.0589E+008$$

$$u = \mu_u \text{ (4.1)} = 9.0418593E-006$$

Calculation of ratio l_b/l_d

$$\text{Lap Length: } l_b/l_d = 0.26680993$$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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: $f_y = 555.55$

$$f'_c = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 16.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 420034.424$

Calculation of Shear Strength at edge 1, $V_{r1} = 420034.424$

$$V_{r1} = V_{Co1} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Co10}$$

$$V_{Co10} = 420034.424$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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).

$$= 1 \text{ (normal-weight concrete)}$$

$$f'_c = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 47.24078$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 73486.813$$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s1} is multiplied by $Col1 = 0.83333333$

$$s/d = 0.79166667$$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$
 Vs2 is multiplied by Col2 = 0.00
 $s/d = 1.90$
 $V_f((11-3)-(11.4), \text{ACI 440}) = 293495.545$
 $f = 0.95$, 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 θ 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (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, $V_{r2} = 420034.424$
 $V_{r2} = V_{Col}((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 420034.424$
 $k_{nl} = 1$ (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).

$\beta = 1$ (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: $V_s = V_{s1} + V_{s2} = 73486.813$
 where:
 $V_{s1} = 73486.813$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$
 V_{s1} is multiplied by Col1 = 0.83333333
 $s/d = 0.79166667$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$
 V_{s2} is multiplied by Col2 = 0.00
 $s/d = 1.90$
 $V_f((11-3)-(11.4), \text{ACI 440}) = 293495.545$
 $f = 0.95$, 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 θ 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

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, = 1.00
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Primary 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
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length lo = 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, $V_e/V_r = 0.60501747$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$

with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.8119E+008$
 $Mu_{1+} = 3.8119E+008$, 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
 $Mu_{1-} = 2.0589E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.8119E+008$
 $Mu_{2+} = 3.8119E+008$, 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
 $Mu_{2-} = 2.0589E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.0933130E-005$

$M_u = 3.8119E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_c : $\phi_c^* = \text{shear_factor} * \text{Max}(\phi_c, \phi_c) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_c = 0.014005$

where ϕ_c ((5.4c), TBDY) = $\phi_c^* * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

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, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$
The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 3525.00$ is 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).

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00127056$

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)

$psh_{,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$psh_{,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$s = 380.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
 c = confinement factor = 1.0981

$y_1 = 0.0011992$
 $sh_1 = 0.00414446$
 $ft_1 = 345.3682$
 $fy_1 = 287.8069$
 $su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.26680993$

$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $fs_1 = fs_1/1.2$, 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 $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.26680993$

$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $es_{2,nominal}$ 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 $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$s_{uv} = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.26680993$

$s_{uv} = 0.4 \cdot es_{uv,nominal} ((5.5), TBDY) = 0.032$

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 $f_{sv} = fs = 287.8069$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.18050973$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08570966$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.15973163$

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 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.25103346$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.11919574$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.22213752$

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

--->

$s_u (4.8) = 0.31943706$

$M_u = MR_c (4.15) = 3.8119E+008$

$u = s_u (4.1) = 1.0933130E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$

$lb = 300.00$

$ld = 1124.396$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.03342$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 16.00$

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.0418593E-006$$

$$Mu = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00127056
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 380.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102
c = confinement factor = 1.0981

y1 = 0.0011992
sh1 = 0.00414446

ft1 = 345.3682
fy1 = 287.8069

su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es1 = Es = 200000.00

y2 = 0.0011992
sh2 = 0.00414446

ft2 = 345.3682
fy2 = 287.8069

su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es2 = Es = 200000.00

yv = 0.0011992
shv = 0.00414446

ftv = 345.3682
fyv = 287.8069

suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03571236

2 = Asl,com/(b*d)*(fs2/fc) = 0.07521239

v = Asl,mid/(b*d)*(fsv/fc) = 0.06655485

and confined core properties:

b = 540.00

$d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04193924$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08832659$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0781595$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17708486$
 $Mu = MRc (4.14) = 2.0589E+008$
 $u = su (4.1) = 9.0418593E-006$

 Calculation of ratio l_b/l_d

 Lap Length: $l_b/l_d = 0.26680993$
 $l_b = 300.00$
 $l_d = 1124.396$
 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)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.03342$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis
 $s = 380.00$
 $n = 16.00$

 Calculation of Mu_{2+}

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.0933130E-005$
 $Mu = 3.8119E+008$

 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 : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.014005$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.014005$
 $we ((5.4c), TBDY) = ase^* sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$
 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 = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$
 $b_{max} = 600.00$

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 = $Max(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.00781147$
The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 3525.00$ is 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).

$psh,min = Min(psh,x, psh,y) = 0.00127056$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
Lstir (Length of stirrups along Y) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 380.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
c = confinement factor = 1.0981

y1 = 0.0011992
sh1 = 0.00414446
ft1 = 345.3682
fy1 = 287.8069
su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = $lb/d = 0.26680993$

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 $fs1 = fs = 287.8069$

with $Es1 = Es = 200000.00$

$y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 0.26680993$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = fs = 287.8069$
 with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $fy_v = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 0.26680993$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 287.8069$
 with $Esv = Es = 200000.00$

$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.18050973$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.08570966$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.15973163$

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.25103346$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.11919574$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.22213752$

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

--->
 $su (4.8) = 0.31943706$
 $Mu = MRc (4.15) = 3.8119E+008$
 $u = su (4.1) = 1.0933130E-005$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.26680993$
 $lb = 300.00$
 $ld = 1124.396$
 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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.03342$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 16.00$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.0418593E-006$

$M_u = 2.0589E+008$

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 μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.014005$

where $\mu_{cc}((5.4c), \text{TBDY}) = \alpha_1 s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

where $f = \alpha_1 * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.06888919$

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, $t_f = N L * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$

The definitions of A_{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.

$A_{conf,min} = 3525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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)

 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00298102$

$c = \text{confinement factor} = 1.0981$

$y_1 = 0.0011992$

$sh_1 = 0.00414446$

$ft_1 = 345.3682$

$fy_1 = 287.8069$

$su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_0/l_{ou,min} = l_b/l_d = 0.26680993$

$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$

$sh_2 = 0.00414446$

$ft_2 = 345.3682$

$fy_2 = 287.8069$

$su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_0/l_{ou,min} = l_b/l_{b,min} = 0.26680993$

$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$su_v = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_0/l_{ou,min} = l_b/l_d = 0.26680993$

$su_v = 0.4 * esuv_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $f_{sv} = f_s = 287.8069$

with $E_{sv} = E_s = 200000.00$

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03571236$

2 = $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07521239$

v = $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06655485$

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 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04193924$

2 = $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08832659$

v = $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.0781595$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < $v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.17708486

Mu = MRc (4.14) = 2.0589E+008

u = su (4.1) = 9.0418593E-006

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$l_b = 300.00$

$l_d = 1124.396$

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 = 1.03342

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

s = 380.00

n = 16.00

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 420034.424$

Calculation of Shear Strength at edge 1, $V_{r1} = 420034.424$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$

$V_{Col0} = 420034.424$

$k_{nl} = 1$ (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 = 47.23669

Vu = 0.00016213

$$d = 0.8 \cdot h = 480.00$$

$$Nu = 8883.864$$

$$Ag = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 73486.813$$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s1} is multiplied by $Col1 = 0.00$

$$s/d = 1.90$$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s2} is multiplied by $Col2 = 0.83333333$

$$s/d = 0.79166667$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \alpha + \cos \alpha$ is replaced with $(\cot \alpha + \cot \alpha) \sin \alpha$ which is more a generalised expression,

where α 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 α_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: $\alpha = b1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|), \text{ with:}$$

total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$

$$dfv = d \text{ (figure 11.2, ACI 440)} = 557.00$$

$$ffe \text{ ((11-5), ACI 440)} = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 356502.845$$

$$bw = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 420034.424$

$$V_{r2} = V_{Col} \text{ ((10.3), ASCE 41-17)} = knl \cdot V_{Col0}$$

$$V_{Col0} = 420034.424$$

$knl = 1$ (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)

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$Mu = 47.23667$$

$$Vu = 0.00016213$$

$$d = 0.8 \cdot h = 480.00$$

$$Nu = 8883.864$$

$$Ag = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 73486.813$$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s1} is multiplied by $Col1 = 0.00$

$$s/d = 1.90$$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

s = 380.00

Vs2 is multiplied by Col2 = 0.83333333

s/d = 0.79166667

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 θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(θ), is implemented for every different fiber orientation ai, as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, θ_1)|, |Vf(-45, θ_1)|), with:

total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$

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 <= 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, $\gamma = 1.00$

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 Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 600.00$

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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $\text{NoDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -1.2946E+007$

Shear Force, $V2 = -4259.045$

Shear Force, $V3 = 148.2786$

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: $A_{s,ten} = 1746.726$

-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 $u_{,R} = * u = 0.04881915$

$u = y + p = 0.04881915$

- Calculation of y -

$y = (M \cdot L_s / 3) / E_{eff} = 0.00681915$ ((4.29), Biskinis Phd))

$M_y = 2.8215E+008$

$L_s = M/V$ (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 y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 3.8958781E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 267.1762$

$d = 557.00$

$y = 0.38438772$

$A = 0.02985949$

$B = 0.01924174$

with $pt = 0.01254381$

$pc = 0.00595605$

$pv = 0.01109992$

$N = 9662.362$

$b = 250.00$

$\rho = 0.07719928$

$y_{comp} = 8.1947240E-006$

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 = 0.38318842
A = 0.02940142
B = 0.01898202
with Es = 200000.00

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.33351241$

$l_b = 300.00$

$l_d = 899.5167$

Calculation of λ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\lambda = 1$

$d_b = 18.00$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.03342$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 16.00$

- Calculation of ρ -

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 $V_y E / V_{col} O E = 0.60501747$

$d = 557.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, 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.

$NUD = 9662.362$

$A_g = 237500.00$

$f_c E = 20.00$

$f_y E = f_y I E = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_c E = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 13

column C1, Floor 1

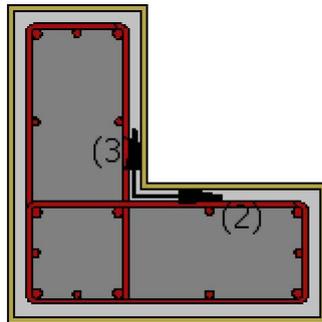
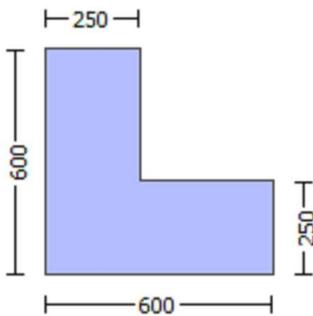
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

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, $\gamma = 1.00$

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 Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ 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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

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, $M_a = -1.2946E+007$

Shear Force, $V_a = -4259.045$

EDGE -B-

Bending Moment, $M_b = 164093.875$

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, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 440357.631$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{Co10} = 440357.631$

$V_{Co10} = 440357.631$

$k_n = 1.00$

$displacement_ductility_demand = 0.07090929$

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)

$M/V_d = 2.00$

$M_u = 164093.875$

$V_u = 4259.045$

$d = 0.8 \cdot h = 480.00$

$N_u = 9662.362$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 66138.793$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.90$

$V_{s2} = 66138.793$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 400.00$

$$s = 380.00$$

$$Vs2 \text{ is multiplied by } Col2 = 0.83333333$$

$$s/d = 0.79166667$$

$$Vf \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$wf/sf = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ 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 α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \theta_1 = \theta_1 + 90^\circ = 90.00$$

$$Vf = \text{Min}(|Vf(45, \theta_1)|, |Vf(-45, \theta_1)|), \text{ with:}$$

$$\text{total thickness per orientation, } tf1 = NL * t / NoDir = 1.016$$

$$dfv = d \text{ (figure 11.2, ACI 440)} = 557.00$$

$$ffe \text{ ((11-5), ACI 440)} = 259.312$$

$$Ef = 64828.00$$

$$fe = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } fu = 0.01$$

$$\text{From (11-11), ACI 440: } Vs + Vf \leq 318865.838$$

$$bw = 250.00$$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END B -

for rotation axis 3 and integ. section (b)

From analysis, chord rotation $\theta = 4.7725017E-005$

$$y = (My * Ls / 3) / Eleff = 0.00067304 \text{ ((4.29), Biskinis Phd)}$$

$$My = 2.8215E+008$$

$$Ls = M/V \text{ (with } Ls > 0.1 * L \text{ and } Ls < 2 * L) = 300.00$$

$$\text{From table 10.5, ASCE 41_17: } Eleff = \text{factor} * Ec * Ig = 4.1921E+013$$

$$\text{factor} = 0.30$$

$$Ag = 237500.00$$

$$fc' = 20.00$$

$$N = 9662.362$$

$$Ec * Ig = 1.3974E+014$$

Calculation of Yielding Moment My

Calculation of δ / y and My according to Annex 7 -

$$y = \text{Min}(y_{ten}, y_{com})$$

$$y_{ten} = 3.8958781E-006$$

$$\text{with ((10.1), ASCE 41-17) } fy = \text{Min}(fy, 1.25 * fy * (lb/d)^{2/3}) = 267.1762$$

$$d = 557.00$$

$$y = 0.38438772$$

$$A = 0.02985949$$

$$B = 0.01924174$$

$$\text{with } pt = 0.01254381$$

$$pc = 0.00595605$$

$$pv = 0.01109992$$

$$N = 9662.362$$

$$b = 250.00$$

$$r = 0.07719928$$

$$y_{comp} = 8.1947240E-006$$

$$\text{with } fc' \text{ (12.3, (ACI 440))} = 20.42407$$

$$fc = 20.00$$

$$fl = 0.62098351$$

$$b = b_{max} = 600.00$$

$$h = h_{max} = 600.00$$

$$Ag = 237500.00$$

$$g = pt + pc + pv = 0.02959978$$

$$rc = 40.00$$

$$A_e/A_c = 0.21783041$$

$$\text{Effective FRP thickness, } t_f = NL \cdot t \cdot \cos(b_1) = 1.016$$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.38318842$$

$$A = 0.02940142$$

$$B = 0.01898202$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,\min} = 0.33351241$

$$l_b = 300.00$$

$$l_d = 899.5167$$

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)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 16.00$$

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

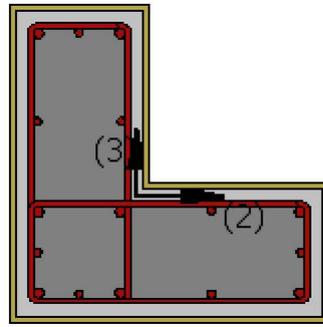
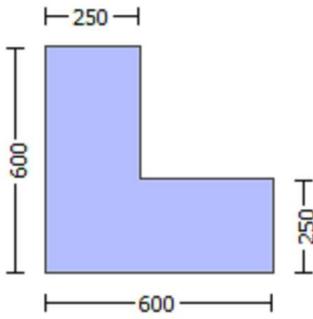
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

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, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$

 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 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, $L = 3000.00$

Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 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: $A_{st} = 0.00$

-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: $A_{s,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.60501747$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$

with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.8119E+008$
 $M_{u1+} = 3.8119E+008$, 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
 $M_{u1-} = 2.0589E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.8119E+008$
 $M_{u2+} = 3.8119E+008$, 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
 $M_{u2-} = 2.0589E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.0933130E-005$

$M_u = 3.8119E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

$\omega (5A.5, \text{TB DY}) = 0.002$

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY: $\phi_u = 0.014005$

where $\phi_u = a_s e^* \phi_{s,min} * f_{y,we} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.0689719$

where $\phi = a_f * \phi_{f,eff} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.06888919$

Expression ((15B.6), TB DY) 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), $\phi_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$\phi_y = 0.06888919$

Expression ((15B.6), TB DY) 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, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$
The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 3525.00$ is 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).

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00127056$

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)

$psh_{,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$psh_{,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$s = 380.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
 $c = \text{confinement factor} = 1.0981$

$y_1 = 0.0011992$
 $sh_1 = 0.00414446$
 $ft_1 = 345.3682$
 $fy_1 = 287.8069$
 $su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.26680993$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.26680993$

$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $es_{u2_nominal}$ 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 $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$s_{uv} = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.26680993$

$s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

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 $f_{sv} = fs = 287.8069$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.18050973$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08570966$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.15973163$

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 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.25103346$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.11919574$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.22213752$

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

--->

$s_u (4.8) = 0.31943706$

$M_u = MR_c (4.15) = 3.8119E+008$

$u = s_u (4.1) = 1.0933130E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$

$lb = 300.00$

$ld = 1124.396$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.03342$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 380.00$

$n = 16.00$

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.0418593E-006$$

$$Mu = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00127056
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 380.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102
c = confinement factor = 1.0981

y1 = 0.0011992
sh1 = 0.00414446

ft1 = 345.3682
fy1 = 287.8069

su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es1 = Es = 200000.00

y2 = 0.0011992
sh2 = 0.00414446

ft2 = 345.3682
fy2 = 287.8069

su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es2 = Es = 200000.00

yv = 0.0011992
shv = 0.00414446

ftv = 345.3682
fyv = 287.8069

suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03571236

2 = Asl,com/(b*d)*(fs2/fc) = 0.07521239

v = Asl,mid/(b*d)*(fsv/fc) = 0.06655485

and confined core properties:

b = 540.00

$d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04193924$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08832659$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.0781595$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17708486$
 $Mu = MRc (4.14) = 2.0589E+008$
 $u = su (4.1) = 9.0418593E-006$

 Calculation of ratio l_b/l_d

 Lap Length: $l_b/l_d = 0.26680993$
 $l_b = 300.00$
 $l_d = 1124.396$
 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)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.03342$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis
 $s = 380.00$
 $n = 16.00$

 Calculation of Mu_{2+}

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.0933130E-005$
 $Mu = 3.8119E+008$

 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 : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.014005$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.014005$
 $we ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$
 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 = $Max(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.00781147$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 3525.00$ is 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).

$psh,min = Min(psh,x, psh,y) = 0.00127056$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
Lstir (Length of stirrups along Y) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 380.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
c = confinement factor = 1.0981

y1 = 0.0011992
sh1 = 0.00414446
ft1 = 345.3682
fy1 = 287.8069
su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = $lb/d = 0.26680993$

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 $fs1 = fs = 287.8069$

with $Es1 = Es = 200000.00$

$y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 0.26680993$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = fs = 287.8069$
 with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $fy_v = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 0.26680993$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 287.8069$
 with $Esv = Es = 200000.00$

$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.18050973$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.08570966$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.15973163$

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.25103346$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.11919574$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.22213752$

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

--->
 $su (4.8) = 0.31943706$
 $Mu = MRc (4.15) = 3.8119E+008$
 $u = su (4.1) = 1.0933130E-005$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.26680993$
 $lb = 300.00$
 $ld = 1124.396$
 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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.03342$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 16.00$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.0418593E-006$

$M_u = 2.0589E+008$

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 μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.014005$

where μ_{cc} ((5.4c), TBDY) = $\alpha_1 \text{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

where $f = \alpha_1 \text{pf} * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as $\alpha_1 f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_1 f = 0.24098246$

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), $\text{pf} = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

 $f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $\alpha_1 f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_1 f = 0.24098246$

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), $\text{pf} = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

 $R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$\alpha_1 \text{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$

The definitions of A_{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.

$A_{conf,min} = 3525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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)

 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00298102$

c = confinement factor = 1.0981

$y_1 = 0.0011992$

$sh_1 = 0.00414446$

$ft_1 = 345.3682$

$fy_1 = 287.8069$

$su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_0/l_{ou,min} = l_b/l_d = 0.26680993$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$

$sh_2 = 0.00414446$

$ft_2 = 345.3682$

$fy_2 = 287.8069$

$su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_0/l_{ou,min} = l_b/l_{b,min} = 0.26680993$

$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$su_v = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_0/l_{ou,min} = l_b/l_d = 0.26680993$

$su_v = 0.4 * esu_{v,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{v,nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, 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 $f_{sv} = f_s = 287.8069$

with $E_{sv} = E_s = 200000.00$

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03571236$

2 = $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07521239$

v = $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06655485$

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 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04193924$

2 = $A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08832659$

v = $A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.0781595$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < $v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.17708486

Mu = MRc (4.14) = 2.0589E+008

u = su (4.1) = 9.0418593E-006

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$l_b = 300.00$

$l_d = 1124.396$

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 = 1.03342

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = 380.00

n = 16.00

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 420034.424$

Calculation of Shear Strength at edge 1, $V_{r1} = 420034.424$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$

$V_{Col0} = 420034.424$

$k_{nl} = 1$ (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: $Vs = Vs1 + Vs2 = 73486.813$
 where:
 $Vs1 = 73486.813$ is calculated for section web, with:
 $d = 480.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 380.00$
 $Vs1$ is multiplied by $Col1 = 0.83333333$
 $s/d = 0.79166667$
 $Vs2 = 0.00$ is calculated for section flange, with:
 $d = 200.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 380.00$
 $Vs2$ is multiplied by $Col2 = 0.00$
 $s/d = 1.90$
 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 $Vf(\theta, a)$, 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: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, a1)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$
 $dfv = d$ (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: $Vs + Vf \leq 356502.845$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $Vr2 = 420034.424$
 $Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl \cdot VCol0$
 $VCol0 = 420034.424$
 $knl = 1$ (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).

$\gamma_c = 1$ (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: $Vs = Vs1 + Vs2 = 73486.813$
 where:
 $Vs1 = 73486.813$ is calculated for section web, with:
 $d = 480.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 380.00$
 $Vs1$ is multiplied by $Col1 = 0.83333333$
 $s/d = 0.79166667$
 $Vs2 = 0.00$ is calculated for section flange, with:
 $d = 200.00$
 $Av = 157079.633$
 $fy = 444.44$

s = 380.00

Vs2 is multiplied by Col2 = 0.00

s/d = 1.90

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 θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(θ), 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, 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: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, 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 , $V_e/V_r = 0.60501747$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$

with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.8119\text{E}+008$
 $\mu_{1+} = 3.8119\text{E}+008$, 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
 $\mu_{1-} = 2.0589\text{E}+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.8119\text{E}+008$
 $\mu_{2+} = 3.8119\text{E}+008$, 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
 $\mu_{2-} = 2.0589\text{E}+008$, 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 μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.0933130\text{E}-005$

$\mu_u = 3.8119\text{E}+008$

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 μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.014005$

μ_{we} ((5.4c), TBDY) = $a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

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, $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.00781147$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 3525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y1 = 0.0011992$

$sh1 = 0.00414446$

$ft1 = 345.3682$

$fy1 = 287.8069$

$su1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/ld = 0.26680993$

$su1 = 0.4*esu1_{nominal}$ ((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 $f_{s1} = f_s = 287.8069$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.26680993$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{s2} = f_s = 287.8069$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $fy_v = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.26680993$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sv} = f_s = 287.8069$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.18050973$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.08570966$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.15973163$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.25103346$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.11919574$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.22213752$
 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
 --->
 $su (4.8) = 0.31943706$
 $Mu = MRc (4.15) = 3.8119E+008$
 $u = su (4.1) = 1.0933130E-005$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$
 $l_b = 300.00$
 $l_d = 1124.396$
 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 = 1.03342

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = 380.00

n = 16.00

Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.0418593E-006$

$\mu_1 = 2.0589E+008$

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.014005$

where μ_{cc} ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

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), $f_{f,e} = 703.4155$

 $f_y = 0.06888919$

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, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{f,1} = 0.015$

$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$

The definitions of A_{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 = 3525.00 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) = 0.00127056

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) = 0.00127056

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) = 0.00127056

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 380.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.0011992

sh1 = 0.00414446

ft1 = 345.3682

fy1 = 287.8069

su1 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es1 = Es = 200000.00

y2 = 0.0011992

sh2 = 0.00414446

ft2 = 345.3682

fy2 = 287.8069

su2 = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

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 = 287.8069

with Es2 = Es = 200000.00

yv = 0.0011992

shv = 0.00414446

ftv = 345.3682

fyv = 287.8069

suv = 0.00414446

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.26680993

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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.

with $fsv = fs = 287.8069$

with $Esv = Es = 200000.00$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.03571236$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.07521239$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.06655485$$

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.04193924$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.08832659$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.0781595$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < vs,y2$ - LHS eq.(4.5) is satisfied

$$su (4.9) = 0.17708486$$

$$Mu = MRc (4.14) = 2.0589E+008$$

$$u = su (4.1) = 9.0418593E-006$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$

$$lb = 300.00$$

$$ld = 1124.396$$

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: $fy = 555.55$

$$fc' = 20.00, \text{ but } fc'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 1.03342$$

$$Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$$

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 16.00$$

Calculation of $Mu2+$

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0933130E-005$$

$$Mu = 3.8119E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 3525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.0011992$$

$$s_{h1} = 0.00414446$$

$$f_{t1} = 345.3682$$

$f_{y1} = 287.8069$
 $s_{u1} = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.26680993$
 $s_{u1} = 0.4 * e_{su1,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{s1} = f_s = 287.8069$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $f_{y2} = 287.8069$
 $s_{u2} = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.26680993$
 $s_{u2} = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{s2} = f_s = 287.8069$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $f_{yv} = 287.8069$
 $s_{uv} = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.26680993$
 $s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sv} = f_s = 287.8069$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.18050973$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08570966$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.15973163$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.25103346$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11919574$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.22213752$
 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
 --->
 $s_u (4.8) = 0.31943706$

$$\begin{aligned} \mu_u &= M/R_c(4.15) = 3.8119E+008 \\ u &= s_u(4.1) = 1.0933130E-005 \end{aligned}$$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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: $f_y = 555.55$

$$f'_c = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 16.00$$

 Calculation of μ_u

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 9.0418593E-006$$

$$\mu_u = 2.0589E+008$$

 with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f'_c = 20.00$$

$$c_o(5A.5, \text{ TBDY}) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e((5.4c), \text{ TBDY}) = a_{se} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.0011992$$

$$sh_1 = 0.00414446$$

$$ft_1 = 345.3682$$

$$fy_1 = 287.8069$$

$$su_1 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 0.26680993$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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.

$$\text{with } fs_1 = fs = 287.8069$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0011992$$

$$sh_2 = 0.00414446$$

$$ft_2 = 345.3682$$

$$fy_2 = 287.8069$$

$$su_2 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_{b,min} = 0.26680993$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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 $f_{s2} = f_s = 287.8069$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $fy_v = 287.8069$
 $su_v = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.26680993$
 $su_v = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 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, 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 $f_{sv} = f_s = 287.8069$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.03571236$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07521239$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.06655485$

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.04193924$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.08832659$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.0781595$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

$su (4.9) = 0.17708486$
 $\mu = MR_c (4.14) = 2.0589E+008$
 $u = su (4.1) = 9.0418593E-006$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$l_b = 300.00$

$l_d = 1124.396$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.03342$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 16.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 420034.424$

Calculation of Shear Strength at edge 1, $Vr1 = 420034.424$

$Vr1 = VCol$ ((10.3), ASCE 41-17) = $knl * VColO$

$VColO = 420034.424$

$knl = 1$ (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: $Vs = Vs1 + Vs2 = 73486.813$

where:

$Vs1 = 0.00$ is calculated for section web, with:

$d = 200.00$

$Av = 157079.633$

$fy = 444.44$

$s = 380.00$

$Vs1$ is multiplied by $Col1 = 0.00$

$s/d = 1.90$

$Vs2 = 73486.813$ is calculated for section flange, with:

$d = 480.00$

$Av = 157079.633$

$fy = 444.44$

$s = 380.00$

$Vs2$ is multiplied by $Col2 = 0.83333333$

$s/d = 0.79166667$

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: $\theta = b1 + 90^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, 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, $Vr2 = 420034.424$

$Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl * VColO$

$VColO = 420034.424$

$knl = 1$ (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: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.90$

$V_{s2} = 73486.813$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $Col2 = 0.833333333$

$s/d = 0.791666667$

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 $V_f(a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $a_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (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, $\gamma = 1.00$

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 Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 600.00$

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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -122390.947$
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, $D_bL = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.04385179$
 $u = y + p = 0.04385179$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00185179$ ((4.29), Biskinis Phd)
 $M_y = 2.8215E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 825.4121
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9662.362$
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.8958781E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 267.1762$
 $d = 557.00$
 $y = 0.38438772$
 $A = 0.02985949$
 $B = 0.01924174$
with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9662.362$
 $b = 250.00$
 $" = 0.07719928$

$y_{comp} = 8.1947240E-006$
 with $f_c^* (12.3, (ACI 440)) = 20.42407$
 $f_c = 20.00$
 $f_l = 0.62098351$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $A_g = 237500.00$
 $g = p_t + p_c + p_v = 0.02959978$
 $r_c = 40.00$
 $A_e/A_c = 0.21783041$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38318842$
 $A = 0.02940142$
 $B = 0.01898202$
 with $E_s = 200000.00$

 Calculation of ratio l_b/d

Lap Length: $l_d/d, \min = 0.33351241$

$l_b = 300.00$

$l_d = 899.5167$

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 $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.03342$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 16.00$

 - 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 $V_y E / V_{CoI} E = 0.60501747$

$d = 557.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, 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.

$NUD = 9662.362$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02959978$

$b = 250.00$

$d = 557.00$

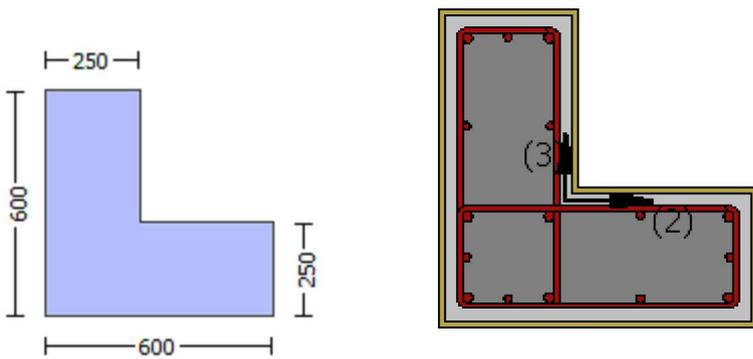
$f_{cE} = 20.00$

 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, $\gamma = 1.00$
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 Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ 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
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length lo = lb = 300.00
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, ffu = 1055.00
Tensile Modulus, Ef = 64828.00
Elongation, efu = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

EDGE -A-
Bending Moment, Ma = -320830.405
Shear Force, Va = 148.2786
EDGE -B-
Bending Moment, Mb = -122390.947
Shear Force, Vb = -148.2786
BOTH EDGES
Axial Force, F = -9662.362
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 = 440357.631
Vn ((10.3), ASCE 41-17) = knl*VCol0 = 440357.631
VCol = 440357.631
knl = 1.00
displacement_ductility_demand = 1.2548606E-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 = 122390.947
Vu = 148.2786
d = 0.8*h = 480.00
Nu = 9662.362
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 66138.793
where:
Vs1 = 66138.793 is calculated for section web, with:

$d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
Vs1 is multiplied by $Col1 = 0.83333333$
 $s/d = 0.79166667$
Vs2 = 0.00 is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
Vs2 is multiplied by $Col2 = 0.00$
 $s/d = 1.90$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, 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 $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:
total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 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: $V_s + V_f \leq 318865.838$
 $bw = 250.00$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END B -
for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 2.3237426E-008$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00185179$ ((4.29), Biskinis Phd)
 $M_y = 2.8215E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 825.4121
From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 4.1921E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9662.362$
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.8958781E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 267.1762$
 $d = 557.00$
 $y = 0.38438772$
 $A = 0.02985949$
 $B = 0.01924174$
with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9662.362$
 $b = 250.00$

$\rho = 0.07719928$
 $y_{comp} = 8.1947240E-006$
 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), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38318842$
 $A = 0.02940142$
 $B = 0.01898202$
 with $E_s = 200000.00$

 Calculation of ratio l_b/l_d

 Lap Length: $l_d/l_{d,min} = 0.33351241$

$l_b = 300.00$

$l_d = 899.5167$

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)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.03342$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 16.00$

 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

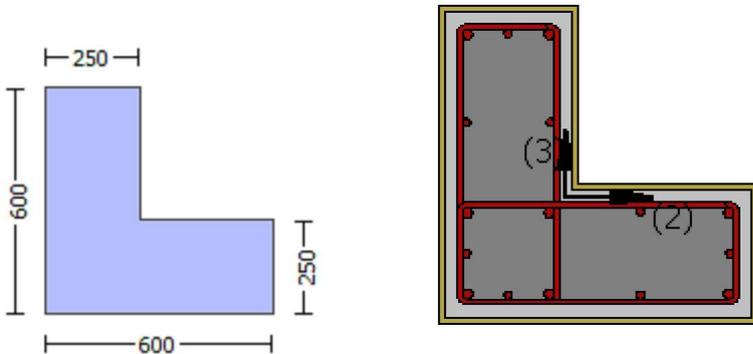
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_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, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

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, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, 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 , $V_e/V_r = 0.60501747$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$
with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.8119\text{E}+008$
 $\mu_{1+} = 3.8119\text{E}+008$, 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
 $\mu_{1-} = 2.0589\text{E}+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.8119\text{E}+008$
 $\mu_{2+} = 3.8119\text{E}+008$, 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
 $\mu_{2-} = 2.0589\text{E}+008$, 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 μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.0933130\text{E}-005$

$\mu_u = 3.8119\text{E}+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00318999$

$N = 8883.864$

$f_c = 20.00$

$\text{co (5A.5, TBDY)} = 0.002$

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \text{cc}) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.014005$

μ_{we} ((5.4c), TBDY) = $\text{ase} * \text{sh}_{,\text{min}} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

where $f = \text{af} * \text{pf} * \text{ffe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area})/(\text{total area})$

$\text{af} = 0.24098246$

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, $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.00781147$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 3525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y1 = 0.0011992$

$sh1 = 0.00414446$

$ft1 = 345.3682$

$fy1 = 287.8069$

$su1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/ld = 0.26680993$

$su1 = 0.4*esu1_{nominal}$ ((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 $f_{s1} = f_s = 287.8069$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.26680993$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{s2} = f_s = 287.8069$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $fy_v = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.26680993$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sv} = f_s = 287.8069$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.18050973$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08570966$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.15973163$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.25103346$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11919574$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.22213752$
 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
 --->
 $su (4.8) = 0.31943706$
 $Mu = MRc (4.15) = 3.8119E+008$
 $u = su (4.1) = 1.0933130E-005$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$
 $l_b = 300.00$
 $l_d = 1124.396$
 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 = 1.03342

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = 380.00

n = 16.00

Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.0418593E-006$

$\mu_1 = 2.0589E+008$

with full section properties:

b = 600.00

d = 557.00

d' = 43.00

v = 0.00132912

N = 8883.864

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.014005$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.014005$

where μ_{cc} ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$

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, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{f,1} = 0.015$

$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$

The definitions of A_{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.

$A_{conf,min} = 3525.00$ is 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).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00127056$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

$c = \text{confinement factor} = 1.0981$

$y_1 = 0.0011992$

$sh_1 = 0.00414446$

$ft_1 = 345.3682$

$fy_1 = 287.8069$

$su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{min} = lb/l_d = 0.26680993$

$su_1 = 0.4 * esu_{1_nominal}$ ((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 $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 287.8069$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0011992$

$sh_2 = 0.00414446$

$ft_2 = 345.3682$

$fy_2 = 287.8069$

$su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{min} = lb/l_{b,min} = 0.26680993$

$su_2 = 0.4 * esu_{2_nominal}$ ((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 $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 287.8069$

with $Es_2 = Es = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$fy_v = 287.8069$

$su_v = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{min} = lb/l_d = 0.26680993$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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 $fsv = fs = 287.8069$

with $Esv = Es = 200000.00$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.03571236$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.07521239$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.06655485$$

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 $= 1.0981$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.04193924$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.08832659$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.0781595$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < vs,y2$ - LHS eq.(4.5) is satisfied

$$su (4.9) = 0.17708486$$

$$Mu = MRc (4.14) = 2.0589E+008$$

$$u = su (4.1) = 9.0418593E-006$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$

$$lb = 300.00$$

$$ld = 1124.396$$

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 $fc'^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 1.03342$$

$$Atr = Min(Atr_x, Atr_y) = 157.0796$$

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 16.00$$

Calculation of $Mu2+$

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0933130E-005$$

$$Mu = 3.8119E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 3525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.0011992$$

$$sh_1 = 0.00414446$$

$$ft_1 = 345.3682$$

$f_{y1} = 287.8069$
 $s_{u1} = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.26680993$
 $s_{u1} = 0.4 * e_{su1,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{s1} = f_s = 287.8069$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $f_{y2} = 287.8069$
 $s_{u2} = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.26680993$
 $s_{u2} = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{s2} = f_s = 287.8069$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $f_{y_v} = 287.8069$
 $s_{u_v} = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.26680993$
 $s_{u_v} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$
 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_{y_v} , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 287.8069$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.18050973$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08570966$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.15973163$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.25103346$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11919574$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.22213752$
 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
 --->
 $s_u (4.8) = 0.31943706$

$$\begin{aligned} \mu_u &= M/R_c(4.15) = 3.8119E+008 \\ u &= s_u(4.1) = 1.0933130E-005 \end{aligned}$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 16.00$$

Calculation of μ_u

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 9.0418593E-006$$

$$\mu_u = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c' = 20.00$$

$$c_o(5A.5, \text{ TBDY}) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e((5.4c), \text{ TBDY}) = a_{se} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 3525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.0011992$$

$$sh_1 = 0.00414446$$

$$ft_1 = 345.3682$$

$$fy_1 = 287.8069$$

$$su_1 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 0.26680993$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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.

$$\text{with } fs_1 = fs = 287.8069$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0011992$$

$$sh_2 = 0.00414446$$

$$ft_2 = 345.3682$$

$$fy_2 = 287.8069$$

$$su_2 = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_{b,min} = 0.26680993$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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 $f_s2 = f_s = 287.8069$
 with $E_s2 = E_s = 200000.00$
 $y_v = 0.0011992$
 $sh_v = 0.00414446$
 $ft_v = 345.3682$
 $fy_v = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.26680993$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = f_s = 287.8069$
 with $Esv = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.03571236$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.07521239$
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.06655485$

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.04193924$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.08832659$
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.0781595$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17708486$
 $Mu = MRc (4.14) = 2.0589E+008$
 $u = su (4.1) = 9.0418593E-006$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$
 $l_b = 300.00$
 $l_d = 1124.396$
 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)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.03342$
 $A_{tr} = Min(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis
 $s = 380.00$
 $n = 16.00$

 Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 420034.424$

Calculation of Shear Strength at edge 1, $Vr1 = 420034.424$

$Vr1 = VCol$ ((10.3), ASCE 41-17) = $knl * VColO$

$VColO = 420034.424$

$knl = 1$ (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: $Vs = Vs1 + Vs2 = 73486.813$

where:

$Vs1 = 73486.813$ is calculated for section web, with:

$d = 480.00$

$Av = 157079.633$

$fy = 444.44$

$s = 380.00$

$Vs1$ is multiplied by $Col1 = 0.83333333$

$s/d = 0.79166667$

$Vs2 = 0.00$ is calculated for section flange, with:

$d = 200.00$

$Av = 157079.633$

$fy = 444.44$

$s = 380.00$

$Vs2$ is multiplied by $Col2 = 0.00$

$s/d = 1.90$

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: $\theta = b1 + 90^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, 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, $Vr2 = 420034.424$

$Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl * VColO$

$VColO = 420034.424$

$knl = 1$ (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: $V_s = V_{s1} + V_{s2} = 73486.813$

where:

$V_{s1} = 73486.813$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.83333333$

$s/d = 0.79166667$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.90$

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 α 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 α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha_1 = \alpha + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (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, $\phi = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

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, $L = 3000.00$

Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
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, $V_e/V_r = 0.60501747$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 254128.164$
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.8119E+008$

$\mu_{1+} = 3.8119E+008$, 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

$\mu_{1-} = 2.0589E+008$, 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.8119E+008$

$\mu_{2+} = 3.8119E+008$, 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

$\mu_{2-} = 2.0589E+008$, 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 μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.0933130E-005$

$M_u = 3.8119E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.014005$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e^* s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.0011992$$

$sh1 = 0.00414446$
 $ft1 = 345.3682$
 $fy1 = 287.8069$
 $su1 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.26680993$
 $su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$
 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 $fs1 = fs = 287.8069$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0011992$
 $sh2 = 0.00414446$
 $ft2 = 345.3682$
 $fy2 = 287.8069$
 $su2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/lb,min = 0.26680993$
 $su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$
 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 $fs2 = fs = 287.8069$
 with $Es2 = Es = 200000.00$
 $yv = 0.0011992$
 $shv = 0.00414446$
 $ftv = 345.3682$
 $fyv = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.26680993$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 287.8069$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.18050973$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.08570966$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.15973163$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.25103346$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.11919574$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.22213752$
 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

--->

$$s_u(4.8) = 0.31943706$$

$$M_u = M_{Rc}(4.15) = 3.8119E+008$$

$$u = s_u(4.1) = 1.0933130E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.26680993$

$$l_b = 300.00$$

$$l_d = 1124.396$$

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: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.03342$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 16.00$$

Calculation of μ_1 -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 9.0418593E-006$$

$$M_u = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } c_u = 0.014005$$

$$\text{we ((5.4c), TB DY) } = a_s e^* s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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), TB DY) 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), TB DY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

bw = 250.00
effective stress from (A.35), $f_{f,e} = 703.4155$

R = 40.00
Effective FRP thickness, $t_f = NL * t * \cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00781147$
The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 3525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$

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)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00127056$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

s = 380.00
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
c = confinement factor = 1.0981

$y_1 = 0.0011992$
 $sh_1 = 0.00414446$
 $ft_1 = 345.3682$
 $fy_1 = 287.8069$
 $su_1 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.26680993$

$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $fs_1 = fs = 287.8069$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.0011992$
 $sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.26680993$

$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s2} = f_s = 287.8069$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0011992$

$sh_v = 0.00414446$

$ft_v = 345.3682$

$f_{y_v} = 287.8069$

$s_{u_v} = 0.00414446$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/d = 0.26680993$

$s_{u_v} = 0.4 \cdot e_{s_{u_v,nominal}} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{s_{u_v,nominal}} = 0.08$,

considering characteristic value $f_{s_{y_v}} = f_{s_v}/1.2$, from table 5.1, TBDY

For calculation of $e_{s_{u_v,nominal}}$ and y_v, sh_v, ft_v, f_{y_v} , it is considered
characteristic value $f_{s_{y_v}} = f_{s_v}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s_v} = f_s = 287.8069$

with $E_{s_v} = E_s = 200000.00$

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03571236$

2 = $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07521239$

v = $A_{s1,mid}/(b \cdot d) \cdot (f_{s_v}/f_c) = 0.06655485$

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 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04193924$

2 = $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08832659$

v = $A_{s1,mid}/(b \cdot d) \cdot (f_{s_v}/f_c) = 0.0781595$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$s_u (4.9) = 0.17708486$

$\mu_u = M_{Rc} (4.14) = 2.0589E+008$

u = $s_u (4.1) = 9.0418593E-006$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.26680993$

$l_b = 300.00$

$l_d = 1124.396$

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

$K_{tr} = 1.03342$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = 380.00

n = 16.00

Calculation of μ_{u2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.0933130E-005$$

$$\mu_u = 3.8119E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.014005$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = \alpha s_e * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.0689719$$

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 $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 0.00$$

$$b_{\text{max}} = 600.00$$

$$h_{\text{max}} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00781147$$

The definitions of A_{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.

$A_{\text{conf,min}} = 3525.00$ 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).

$$p_{sh,\text{min}} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00127056$$

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)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00127056$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$\text{psh,y ((5.4d), TBDY)} = \text{Lstir} \cdot \text{Astir} / (\text{Asec} \cdot \text{s}) = 0.00127056$$

$$\text{Lstir (Length of stirrups along X)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$\text{s} = 380.00$$

$$\text{fywe} = 555.55$$

$$\text{fce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: cc} = 0.00298102$$

$$\text{c} = \text{confinement factor} = 1.0981$$

$$\text{y1} = 0.0011992$$

$$\text{sh1} = 0.00414446$$

$$\text{ft1} = 345.3682$$

$$\text{fy1} = 287.8069$$

$$\text{su1} = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/l d} = 0.26680993$$

$$\text{su1} = 0.4 \cdot \text{esu1_nominal ((5.5), TBDY)} = 0.032$$

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.

$$\text{with fs1} = \text{fs} = 287.8069$$

$$\text{with Es1} = \text{Es} = 200000.00$$

$$\text{y2} = 0.0011992$$

$$\text{sh2} = 0.00414446$$

$$\text{ft2} = 345.3682$$

$$\text{fy2} = 287.8069$$

$$\text{su2} = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/l b,min} = 0.26680993$$

$$\text{su2} = 0.4 \cdot \text{esu2_nominal ((5.5), TBDY)} = 0.032$$

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.

$$\text{with fs2} = \text{fs} = 287.8069$$

$$\text{with Es2} = \text{Es} = 200000.00$$

$$\text{yv} = 0.0011992$$

$$\text{shv} = 0.00414446$$

$$\text{ftv} = 345.3682$$

$$\text{fyv} = 287.8069$$

$$\text{su v} = 0.00414446$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/l d} = 0.26680993$$

$$\text{su v} = 0.4 \cdot \text{esuv_nominal ((5.5), TBDY)} = 0.032$$

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.

$$\text{with fsv} = \text{fs} = 287.8069$$

$$\text{with Es v} = \text{Es} = 200000.00$$

$$1 = \text{Asl,ten} / (\text{b} \cdot \text{d}) \cdot (\text{fs1} / \text{fc}) = 0.18050973$$

$$2 = \text{Asl,com} / (\text{b} \cdot \text{d}) \cdot (\text{fs2} / \text{fc}) = 0.08570966$$

$$\text{v} = \text{Asl,mid} / (\text{b} \cdot \text{d}) \cdot (\text{fsv} / \text{fc}) = 0.15973163$$

and confined core properties:

$$\text{b} = 190.00$$

$$\text{d} = 527.00$$

$$\text{d}' = 13.00$$

$$\text{fcc (5A.2, TBDY)} = 21.96205$$

$$cc \text{ (5A.5, TBDY)} = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$1 = Asl_{ten}/(b*d)*(fs1/fc) = 0.25103346$$

$$2 = Asl_{com}/(b*d)*(fs2/fc) = 0.11919574$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.22213752$$

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

---->
 $su \text{ (4.8)} = 0.31943706$

$$Mu = MRc \text{ (4.15)} = 3.8119E+008$$

$$u = su \text{ (4.1)} = 1.0933130E-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$

$$lb = 300.00$$

$$ld = 1124.396$$

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: $f_y = 555.55$

$$fc' = 20.00, \text{ but } fc^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 1.03342$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 16.00$$

Calculation of Mu_2 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 9.0418593E-006$$

$$Mu = 2.0589E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$fc = 20.00$$

$$co \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.014005$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.014005$$

$$\text{we ((5.4c), TBDY) } = ase * sh_{min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.0689719$$

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 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, $tf = NL*t*Cos(b1) = 1.016$
 $fu,f = 1055.00$
 $Ef = 64828.00$
 $u,f = 0.015$
 $ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.00781147$
The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.
 $A_{conf,min} = 3525.00$ is 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 $b^2/6$ as defined at (A.2).
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00127056$
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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
 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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00127056$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

 $s = 380.00$
 $fywe = 555.55$
 $fce = 20.00$
From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $y1 = 0.0011992$
 $sh1 = 0.00414446$
 $ft1 = 345.3682$
 $fy1 = 287.8069$
 $su1 = 0.00414446$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.26680993$
 $su1 = 0.4*esu1_nominal$ ((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 $fs1 = fs = 287.8069$
with $Es1 = Es = 200000.00$
 $y2 = 0.0011992$

$sh_2 = 0.00414446$
 $ft_2 = 345.3682$
 $fy_2 = 287.8069$
 $su_2 = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 0.26680993$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = fs = 287.8069$
 with $Es_2 = Es = 200000.00$
 $yv = 0.0011992$
 $shv = 0.00414446$
 $ftv = 345.3682$
 $fyv = 287.8069$
 $suv = 0.00414446$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 0.26680993$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 287.8069$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.03571236$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.07521239$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.06655485$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.04193924$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.08832659$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.0781595$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs_y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17708486$
 $Mu = MRc (4.14) = 2.0589E+008$
 $u = su (4.1) = 9.0418593E-006$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.26680993$
 $lb = 300.00$
 $ld = 1124.396$
 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)
 $t = 1.00$
 $s = 0.80$

$e = 1.00$
 $cb = 25.00$
 $Ktr = 1.03342$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 380.00$
 $n = 16.00$

 Calculation of Shear Strength $Vr = \text{Min}(Vr1, Vr2) = 420034.424$

 Calculation of Shear Strength at edge 1, $Vr1 = 420034.424$
 $Vr1 = VCol$ ((10.3), ASCE 41-17) = $knl * VCol0$
 $VCol0 = 420034.424$
 $knl = 1$ (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: $Vs = Vs1 + Vs2 = 73486.813$

where:

$Vs1 = 0.00$ is calculated for section web, with:

$d = 200.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 380.00$

$Vs1$ is multiplied by $Col1 = 0.00$

$s/d = 1.90$

$Vs2 = 73486.813$ is calculated for section flange, with:

$d = 480.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 380.00$

$Vs2$ is multiplied by $Col2 = 0.83333333$

$s/d = 0.79166667$

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 $(\cot + \csc) \sin \alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $Vf(\alpha, a_i)$, 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: $\alpha = b1 + 90^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, a1)|, |Vf(-45, a1)|)$, 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, $Vr2 = 420034.424$

$Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl * VCol0$

$VCol0 = 420034.424$

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 = 73486.813

where:

Vs1 = 0.00 is calculated for section web, with:

d = 200.00

Av = 157079.633

fy = 444.44

s = 380.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.90

Vs2 = 73486.813 is calculated for section flange, with:

d = 480.00

Av = 157079.633

fy = 444.44

s = 380.00

Vs2 is multiplied by Col2 = 0.83333333

s/d = 0.79166667

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 θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(θ), 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, θ)|, |Vf(-45, θ)|), 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: rclcs

Constant Properties

Knowledge Factor, $\phi = 1.00$

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 Primary Member: Concrete Strength, fc = fcm = 20.00

Existing material of Primary 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, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 164093.875$
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 $\phi_{u,R} = \phi_u = 0.04267304$
 $\phi_u = \phi_y + \phi_p = 0.04267304$

- Calculation of ϕ_y -

$\phi_y = (M_y \cdot L_s / 3) / E_{eff} = 0.00067304$ ((4.29), Biskinis Phd))
 $M_y = 2.8215E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 4.1921E+013$
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 ϕ_y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 3.8958781\text{E-}006$
 with $((10.1), \text{ASCE } 41-17) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 267.1762$
 $d = 557.00$
 $y = 0.38438772$
 $A = 0.02985949$
 $B = 0.01924174$
 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: $l_d/d, \text{min} = 0.33351241$
 $l_b = 300.00$
 $l_d = 899.5167$
 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)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.03342$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 380.00$
 $n = 16.00$

 - 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 $V_y E / V_{CoIOE} = 0.60501747$
 $d = 557.00$
 $s = 0.00$
 $t = Av / (bw \cdot s) + 2 \cdot tf / bw \cdot (ffe / fs) = Av \cdot L_{\text{stir}} / (Ag \cdot s) + 2 \cdot tf / bw \cdot (ffe / fs) = 0.00$
 $Av = 78.53982$, 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.

$$N_{UD} = 9662.362$$

$$A_g = 237500.00$$

$$f_{cE} = 20.00$$

$$f_{yE} = f_{yI} = 0.00$$

$$p_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.02959978$$

$$b = 250.00$$

$$d = 557.00$$

$$f_{cE} = 20.00$$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)
