

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

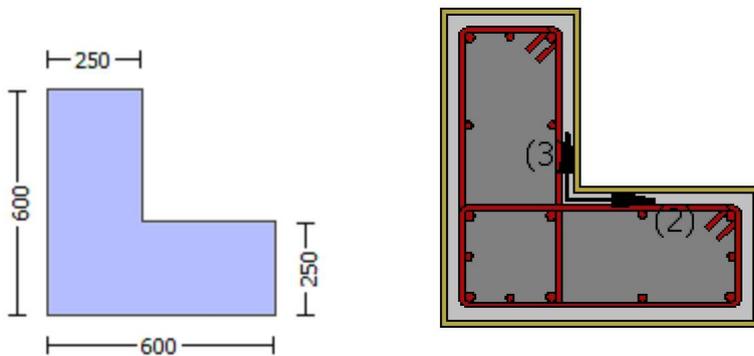
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $E_s = 200000.00$

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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, $f_s = f_{sm} = 444.4444$

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Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -6.8559E+006$

Shear Force, $V_a = -2255.578$

EDGE -B-

Bending Moment, $M_b = 86875.91$

Shear Force, $V_b = 2255.578$

BOTH EDGES

Axial Force, $F = -9297.478$

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 $V_R = \phi V_n = 341618.23$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 379575.812$

$V_{CoI} = 379575.812$

$k_n = 1.00$

displacement_ductility_demand = 0.01056488

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)

$M/Vd = 4.00$

$\mu_u = 6.8559E+006$
 $V_u = 2255.578$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9297.478$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 427256.601$
 where:
 $V_{s1} = 125663.706$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 301592.895$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 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 $\theta = 6.7147804E-005$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00635575$ ((4.29), Biskinis Phd))
 $M_y = 2.6298E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3039.535
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$
 $\text{factor} = 0.30$
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9297.478$
 $E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

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

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.6307935E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 248.9669$
 $d = 557.00$

y = 0.38446193
A = 0.02986796
B = 0.01925021
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9297.478
b = 250.00
" = 0.07719928
y_comp = 8.1956051E-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 = 0.38314723
A = 0.02940891
B = 0.01898202
with Es = 200000.00

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

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

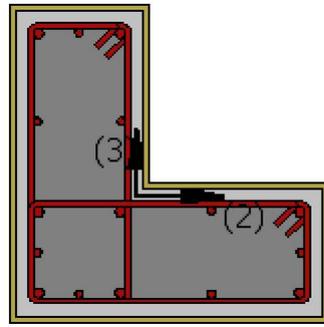
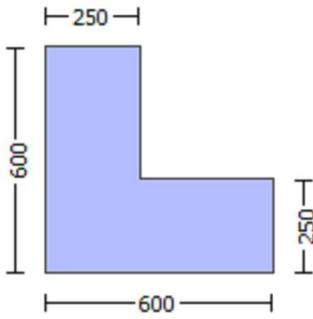
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (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: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$
 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, $f_s = f_{sm} = 444.4444$
 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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

 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 = 1.26976
 Element Length, $L = 3000.00$

Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, $V_a = 0.00016213$
 EDGE -B-
 Shear Force, $V_b = -0.00016213$

BOTH EDGES

Axial Force, $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{,ten} = 1746.726$

-Compression: $As_{,com} = 829.3805$

-Middle: $As_{,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.66001628$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.2000E+008$

$Mu_{1+} = 4.2000E+008$, 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

$Mu_{1-} = 2.3956E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.2000E+008$

$Mu_{2+} = 4.2000E+008$, 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

$Mu_{2-} = 2.3956E+008$, 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:

$\phi_u = 1.3683079E-005$

$M_u = 4.2000E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01648022$

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

From (5.4b), TBDY: $\phi_u = 0.01648022$

where $\phi_u (5.4c, TBDY) = \phi_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.10530374$

where $\phi = \phi_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.06888919$

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

$\phi_{se} = 0.24098246$

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), $\phi_{sh, \min} = 2t_f / b_w = 0.008128$

$b_w = 250.00$

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

$\phi_y = 0.06888919$

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

$\phi_{se} = 0.24098246$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$

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.

$A_{\text{conf,min}} = 122525.00$ 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 $b^2/6$ as defined at (A.2).
 $psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00482813$

$psh_{,x}$ ((5.4d), TBDY) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$

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) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

s = 100.00

$f_{ywe} = 555.5556$

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976

c = confinement factor = 1.26976

$y_1 = 0.0012967$

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

su1 = 0.00512

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

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

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

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

For calculation of $esu1_{\text{nominal}}$ 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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

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

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

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

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

For calculation of $esu2_{\text{nominal}}$ 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.

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

with $fs2 = fs = 311.2087$

with $Es2 = Es = 200000.00$

$yv = 0.0012967$

$shv = 0.0044814$

$ftv = 373.4504$

$fyv = 311.2087$

$suv = 0.00512$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lou, \text{min} = lb/d = 0.30$

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

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

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

For calculation of $esuv_{\text{nominal}}$ and yv, shv, ftv, fyv , it is considered

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

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

with $fsv = fs = 311.2087$

with $Es = Es = 200000.00$

1 = $Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.19518711$

2 = $Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.09267877$

v = $Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.17271953$

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = $Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.27144518$

2 = $Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.12888764$

v = $Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.24019969$

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) = 0.32821401

$Mu = MRc$ (4.15) = 4.2000E+008

u = su (4.1) = 1.3683079E-005

Calculation of ratio lb/d

Inadequate Lap Length with $lb/d = 0.30$

Calculation of $Mu1$ -

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

u = 1.0987593E-005

$Mu = 2.3956E+008$

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 c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$

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

From (5.4b), TBDY: $c_u = 0.01648022$

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

 $f_x = 0.06888919$

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

$a_f = 0.24098246$

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

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

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

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

$b_w = 250.00$

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

 $f_y = 0.06888919$

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

$a_f = 0.24098246$

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

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

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

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

$b_w = 250.00$

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

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$

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.

$A_{\text{conf,min}} = 122525.00$ 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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

Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

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

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

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

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

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

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616

2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796

v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = Asl,ten/(b*d)*(fs1/fc) = 0.04534935

2 = Asl,com/(b*d)*(fs2/fc) = 0.09550849

v = Asl,mid/(b*d)*(fsv/fc) = 0.08451471

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.16341093

Mu = MRc (4.14) = 2.3956E+008

u = su (4.1) = 1.0987593E-005

Calculation of ratio lb/d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{2+}

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

$$\mu = 1.3683079E-005$$

$$\mu_u = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01648022$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$$

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

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

$A_{conf,min} = 122525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

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

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00482813
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976
c = confinement factor = 1.26976

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19518711

2 = Asl,com/(b*d)*(fs2/fc) = 0.09267877

v = Asl,mid/(b*d)*(fsv/fc) = 0.17271953

and confined core properties:

b = 190.00

$d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.27144518$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12888764$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.24019969$
 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
 --->

$su (4.8) = 0.32821401$
 $Mu = MRc (4.15) = 4.2000E+008$
 $u = su (4.1) = 1.3683079E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Mu_2 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.0987593E-005$
 $Mu = 2.3956E+008$

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 : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01648022$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01648022$
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$
 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, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

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

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

$A_{conf,min} = 122525.00$ is 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).

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00482813$

$psh_{,x}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00482813$

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) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00482813$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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

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

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

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

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

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

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$

$sh_2 = 0.0044814$

$ft_2 = 373.4504$

$fy_2 = 311.2087$

$su_2 = 0.00512$

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

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

$su_2 = 0.4 \cdot esu_{2,nominal}$ ((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_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 311.2087$

with $Es_2 = Es = 200000.00$

$y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $su_v = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.30$
 $su_v = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fs_v = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_v = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.03861616$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.08132796$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.07196647$

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.04534935$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.09550849$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08451471$

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

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16341093$
 $Mu = MRc (4.14) = 2.3956E+008$
 $u = su (4.1) = 1.0987593E-005$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

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

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = knl * V_{Co10}$
 $V_{Co10} = 424229.688$
 $knl = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc'^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 46.90894$
 $Vu = 0.00016213$
 $d = 0.8 * h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:

Vs1 = 335103.216 is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs1 is multiplied by Col1 = 1.00

$$s/d = 0.20833333$$

Vs2 = 139626.34 is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.50$$

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

f = 0.95, for fully-wrapped sections

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

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where 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: $\theta = b_1 + 90^\circ = 90.00$

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

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

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

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

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

$$b_w = 250.00$$

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

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

$$V_{Col0} = 424229.688$$

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

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

$\lambda = 1$ (normal-weight concrete)

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

$$M/Vd = 4.00$$

$$M_u = 46.90897$$

$$V_u = 0.00016213$$

$$d = 0.8 \cdot h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$

where:

Vs1 = 335103.216 is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs1 is multiplied by Col1 = 1.00

$$s/d = 0.20833333$$

Vs2 = 139626.34 is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.50$$

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 $V_f(\theta, \alpha)$, 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (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: rdlcs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

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 = 1.26976

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $\text{NoDir} = 1$

Fiber orientations, $\theta_i = 0.00^\circ$

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: $As_t = 0.00$

-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: $As_{c,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.66001628$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$
with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.2000E+008$

$Mu_{1+} = 4.2000E+008$, 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

$Mu_{1-} = 2.3956E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.2000E+008$

$Mu_{2+} = 4.2000E+008$, 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

$Mu_{2-} = 2.3956E+008$, 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:

$\phi_u = 1.3683079E-005$

$M_u = 4.2000E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01648022$

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

From (5.4b), TBDY: $\phi_{cu} = 0.01648022$

where ϕ_{cu} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.10530374$

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

$\phi_{fx} = 0.06888919$

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

$\alpha_{se} = 0.24098246$

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, $t_f = NL * t * \cos(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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

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

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

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

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

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

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$

$sh_2 = 0.0044814$

$ft_2 = 373.4504$

$fy_2 = 311.2087$

$su_2 = 0.00512$

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

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

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,

For calculation of $e_{su2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

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

$$\text{with } f_{s2} = f_s = 311.2087$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{uv} = 0.00512$$

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

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

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

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

considering characteristic value $f_{syv} = f_{sv}/1.2$, 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.

$$\text{with } f_{sv} = f_s = 311.2087$$

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19518711$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09267877$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.17271953$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$cc (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.27144518$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.12888764$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.24019969$$

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

--->

$$s_u (4.8) = 0.32821401$$

$$M_u = M_{Rc} (4.15) = 4.2000E+008$$

$$u = s_u (4.1) = 1.3683079E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u1} -

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

$$u = 1.0987593E-005$$

$$M_u = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01648022$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$p_{sh, \min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

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

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

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

$$p_{sh,y} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

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

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

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

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.0046976$$

$c = \text{confinement factor} = 1.26976$
 $y1 = 0.0012967$
 $sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.30$
 $su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fs1 = fs = 311.2087$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 0.30$
 $su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fs2 = fs = 311.2087$
 with $Es2 = Es = 200000.00$
 $yv = 0.0012967$
 $shv = 0.0044814$
 $ftv = 373.4504$
 $fyv = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.30$
 $suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.03861616$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.08132796$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.07196647$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 25.3952$
 $cc (5A.5, \text{TBDY}) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.04534935$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.09550849$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.08451471$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.16341093$$

$$M_u = M_{Rc}(4.14) = 2.3956E+008$$

$$u = s_u(4.1) = 1.0987593E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u2+}

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

$$u = 1.3683079E-005$$

$$M_u = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01648022$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01648022$$

$$\omega_e(5.4c, TBDY) = a_s e^* s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.10530374$$

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

$$\phi_x = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$\phi_y = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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.

Aconf,min = 122525.00 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) = 0.00482813

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00482813
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) = 0.00482813
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00

fywe = 555.5556

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976

c = confinement factor = 1.26976

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

su1 = 0.00512

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

lo/lou,min = lb/l_d = 0.30

su1 = 0.4*esu1_nominal ((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 = fs/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/l_d)^2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

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

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

su2 = 0.4*esu2_nominal ((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 = fs/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/l_d)^2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

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

lo/lou,min = lb/l_d = 0.30

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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 $f_{sv} = f_s = 311.2087$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.19518711$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09267877$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.17271953$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 25.3952$

$cc (5A.5, TBDY) = 0.0046976$

$c = \text{confinement factor} = 1.26976$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.27144518$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12888764$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.24019969$

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

--->

$su (4.8) = 0.32821401$

$Mu = MRc (4.15) = 4.2000E+008$

$u = su (4.1) = 1.3683079E-005$

Calculation of ratio lb/d

Inadequate Lap Length with $lb/d = 0.30$

Calculation of Mu_2 -

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

$u = 1.0987593E-005$

$Mu = 2.3956E+008$

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 : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01648022$

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

From (5.4b), TBDY: $cu = 0.01648022$

$w_e ((5.4c), TBDY) = a_{se} \cdot sh_{,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$

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), $f_{fe} = 703.4155$

$f_y = 0.06888919$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.27151783$

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

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

$A_{conf,min} = 122525.00$ is 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).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00482813$

psh_x ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

c = confinement factor = 1.26976

$y1 = 0.0012967$

$sh1 = 0.0044814$

$ft1 = 373.4504$

$fy1 = 311.2087$

$su1 = 0.00512$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

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

$su1 = 0.4*es_{u1_nominal}$ ((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 $\text{Min}(1, 1.25*(l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y2 = 0.0012967$

$sh2 = 0.0044814$

$ft2 = 373.4504$

$fy2 = 311.2087$

$su2 = 0.00512$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

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

$$s_u2 = 0.4 * e_{s_u2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_u2,nominal} = 0.08$,

For calculation of $e_{s_u2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{s_y2} = f_{s_2}/1.2$, 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.

$$\text{with } f_{s_2} = f_s = 311.2087$$

$$\text{with } E_{s_2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{u_v} = 0.00512$$

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

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

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

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

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

For calculation of $e_{s_{u_v},nominal}$ and y_v, sh_v, ft_v, fy_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, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s_v} = f_s = 311.2087$$

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

$$1 = A_{s_l,ten}/(b*d)*(f_{s_1}/f_c) = 0.03861616$$

$$2 = A_{s_l,com}/(b*d)*(f_{s_2}/f_c) = 0.08132796$$

$$v = A_{s_l,mid}/(b*d)*(f_{s_v}/f_c) = 0.07196647$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$c_c (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{s_l,ten}/(b*d)*(f_{s_1}/f_c) = 0.04534935$$

$$2 = A_{s_l,com}/(b*d)*(f_{s_2}/f_c) = 0.09550849$$

$$v = A_{s_l,mid}/(b*d)*(f_{s_v}/f_c) = 0.08451471$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16341093$$

$$\mu_u = M_{Rc} (4.14) = 2.3956E+008$$

$$u = s_u (4.1) = 1.0987593E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

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

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} * V_{Co1}$$

$$V_{Co1} = 424229.688$$

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

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

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

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

$M/Vd = 4.00$
 $\mu = 46.90488$
 $\nu = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:
 $V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 335103.216$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 V_f ((11-3)-(11.4), ACI 440) = 293495.545
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{ColO}$
 $V_{ColO} = 424229.688$
 $k_{nl} = 1$ (zero step-static loading)

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

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu = 46.90486$
 $\nu = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:
 $V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 335103.216$ is calculated for section flange, with:

$d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 Vs2 is multiplied by Col2 = 1.00
 $s/d = 0.20833333$
 $V_f((11-3)-(11.4), \text{ACI 440}) = 293495.545$
 $f = 0.95$, 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 a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

 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: rdcS

Constant Properties

 Knowledge Factor, $\gamma = 0.90$
 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, $f_s = f_{sm} = 444.4444$
 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
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_b/l_d = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $\text{NoDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$

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

Stepwise Properties

Bending Moment, M = -171049.041
Shear Force, V2 = -2255.578
Shear Force, V3 = 79.07961
Axial Force, F = -9297.478
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 $u,R = * u = 0.0040706$
 $u = y + p = 0.00452289$

- Calculation of y -

$y = (My * Ls / 3) / Eleff = 0.00452289$ ((4.29), Biskinis Phd)
My = 2.6298E+008
Ls = M/V (with Ls > 0.1*L and Ls < 2*L) = 2162.998
From table 10.5, ASCE 41_17: Eleff = factor * Ec * Ig = 4.1921E+013
factor = 0.30
Ag = 237500.00
fc' = 20.00
N = 9297.478
Ec * Ig = 1.3974E+014

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.6307935E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 248.9669$
d = 557.00
y = 0.38446193
A = 0.02986796
B = 0.01925021
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9297.478
b = 250.00
" = 0.07719928
 $y_{comp} = 8.1956051E-006$
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, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38314723$
 $A = 0.02940891$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

- 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 $V_y E / V_c I_{OE} = 0.66001628$

$d = 557.00$

$s = 0.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = A_v \cdot L_{stir} / (A_g \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ 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.

$NUD = 9297.478$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

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

At local axis: 2

Integration Section: (a)

Calculation No. 3

column C1, Floor 1

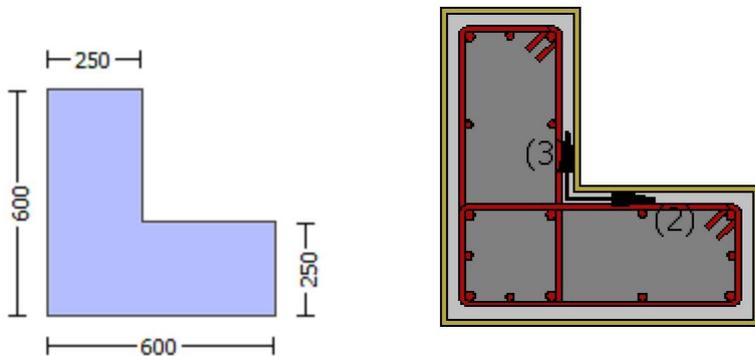
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$

#####

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

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -171049.041$
Shear Force, $V_a = 79.07961$
EDGE -B-
Bending Moment, $M_b = -65334.277$
Shear Force, $V_b = -79.07961$
BOTH EDGES
Axial Force, $F = -9297.478$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_{lt} = 0.00$
-Compression: $As_{lc} = 4121.77$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 1746.726$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 1545.664$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 341618.23$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 379575.812$
 $V_{CoI} = 379575.812$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.00555743$

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).

 $\phi = 1$ (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 171049.041$
 $V_u = 79.07961$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9297.478$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 427256.601$
where:
 $V_{s1} = 301592.895$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.20833333$
 $V_{s2} = 125663.706$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 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 $V_f(\theta, \alpha_i)$, 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 $\theta = 2.5135664E-005$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00452289$ ((4.29), Biskinis Phd)

$M_y = 2.6298E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 2162.998

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

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9297.478$

$E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

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

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

$y_{\text{ten}} = 3.6307935E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 248.9669$

$d = 557.00$

$y = 0.38446193$

$A = 0.02986796$

$B = 0.01925021$

with $p_t = 0.01254381$

$p_c = 0.00595605$

$p_v = 0.01109992$

$N = 9297.478$

$b = 250.00$

$\alpha = 0.07719928$

$y_{\text{comp}} = 8.1956051E-006$

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), $e_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.38314723$

A = 0.02940891
B = 0.01898202
with Es = 200000.00

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

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

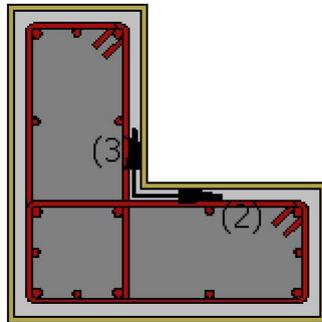
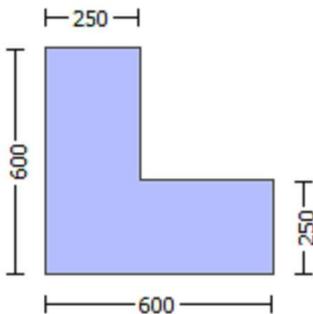
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

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 = 1.26976

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00016213$

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 , $V_e/V_r = 0.66001628$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$

with
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 4.2000E+008$
 $M_{u1+} = 4.2000E+008$, 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
 $M_{u1-} = 2.3956E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 4.2000E+008$
 $M_{u2+} = 4.2000E+008$, 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
 $M_{u2-} = 2.3956E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

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

$$\mu = 1.3683079E-005$$

$$Mu = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01648022$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01648022$$

$$\mu_e \text{ ((5.4c), TBDY)} = a_s e^* \frac{\text{sh}_{,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y)}{f} = 0.10530374$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00

fywe = 555.5556

fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.0046976

c = confinement factor = 1.26976

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

su1 = 0.00512

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

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

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

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

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

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

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19518711

2 = Asl,com/(b*d)*(fs2/fc) = 0.09267877

v = Asl,mid/(b*d)*(fsv/fc) = 0.17271953

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = $Asl_{ten}/(b*d)*(fs1/fc) = 0.27144518$

2 = $Asl_{com}/(b*d)*(fs2/fc) = 0.12888764$

v = $Asl_{mid}/(b*d)*(fsv/fc) = 0.24019969$

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) = 0.32821401

Mu = MRc (4.15) = 4.2000E+008

u = su (4.1) = 1.3683079E-005

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu1-

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

u = 1.0987593E-005

Mu = 2.3956E+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: $cu^* = shear_factor * Max(cu, cc) = 0.01648022$

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

From (5.4b), TBDY: $cu = 0.01648022$

we ((5.4c), TBDY) = $ase * sh_{,min} * fy_{we}/f_{ce} + Min(f_x, f_y) = 0.10530374$

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 $af = 1 - (Unconfined\ area)/(total\ area)$

$af = 0.24098246$

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 $af = 1 - (Unconfined\ area)/(total\ area)$

$af = 0.24098246$

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, $tf = NL * t * Cos(b1) = 1.016$

$f_{u,f} = 1055.00$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$$

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

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

$A_{conf,min} = 122525.00$ is 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).

$$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00482813$$

$$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

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

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

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

$$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

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

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

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

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

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

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

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

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.

$$\text{with } fs_1 = fs = 311.2087$$

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

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$su_2 = 0.00512$$

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

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

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

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.

$$\text{with } fs_2 = fs = 311.2087$$

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

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616

2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796

v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = Asl,ten/(b*d)*(fs1/fc) = 0.04534935

2 = Asl,com/(b*d)*(fs2/fc) = 0.09550849

v = Asl,mid/(b*d)*(fsv/fc) = 0.08451471

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.16341093

Mu = MRc (4.14) = 2.3956E+008

u = su (4.1) = 1.0987593E-005

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2+

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

u = 1.3683079E-005

Mu = 4.2000E+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* = shear_factor * Max(cu, cc) = 0.01648022

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

From (5.4b), TBDY: cu = 0.01648022

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.10530374

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

$b_{max} = 600.00$

$h_{max} = 600.00$

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

$b_w = 250.00$

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

$f_y = 0.06888919$

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

$af = 0.24098246$

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), $pf = 2t_f/b_w = 0.008128$

$b_w = 250.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}), 0) = 0.27151783$

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

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

$A_{conf,min} = 122525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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

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

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

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

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

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

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

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

lo/lou,min = lb/ld = 0.30

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19518711

2 = Asl,com/(b*d)*(fs2/fc) = 0.09267877

v = Asl,mid/(b*d)*(fsv/fc) = 0.17271953

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = Asl,ten/(b*d)*(fs1/fc) = 0.27144518

2 = Asl,com/(b*d)*(fs2/fc) = 0.12888764

v = Asl,mid/(b*d)*(fsv/fc) = 0.24019969

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) = 0.32821401

Mu = MRc (4.15) = 4.2000E+008

u = su (4.1) = 1.3683079E-005

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu2-

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

$$u = 1.0987593E-005$$

$$Mu = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01648022$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01648022$$

$$\phi_{we} \text{ ((5.4c), TBDY) } = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.10530374$$

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

$$\phi_{fx} = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$\phi_{fy} = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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)

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

$A_{\text{conf,min}} = 122525.00$ 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).

$$\phi_{\text{psh,min}} = \text{Min}(\phi_{\text{psh,x}}, \phi_{\text{psh,y}}) = 0.00482813$$

$$\phi_{\text{psh,x}} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

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

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

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

$$\phi_{\text{psh,y}} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

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

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

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

$s = 100.00$
 $fy_{we} = 555.5556$
 $f_{ce} = 20.00$
 From ((5.A.5), TBDY), TBDY: $cc = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $y_1 = 0.0012967$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4504$
 $fy_1 = 311.2087$
 $su_1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/d = 0.30$
 $su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_1 \text{ nominal} = 0.08$,
 For calculation of $esu_1 \text{ nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 311.2087$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.0012967$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4504$
 $fy_2 = 311.2087$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 0.30$
 $su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_2 \text{ nominal} = 0.08$,
 For calculation of $esu_2 \text{ nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 311.2087$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/d = 0.30$
 $suv = 0.4 * esuv \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esuv \text{ nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv \text{ nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten}/(b * d) * (fs_1/fc) = 0.03861616$
 $2 = Asl, \text{com}/(b * d) * (fs_2/fc) = 0.08132796$
 $v = Asl, \text{mid}/(b * d) * (fsv/fc) = 0.07196647$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} \text{ (5A.2, TBDY)} = 25.3952$
 $cc \text{ (5A.5, TBDY)} = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl, \text{ten}/(b * d) * (fs_1/fc) = 0.04534935$
 $2 = Asl, \text{com}/(b * d) * (fs_2/fc) = 0.09550849$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08451471$$

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

--->

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

--->

$$s_u(4.9) = 0.16341093$$

$$M_u = M_{Rc}(4.14) = 2.3956E+008$$

$$u = s_u(4.1) = 1.0987593E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

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

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

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

$$V_{Col0} = 424229.688$$

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

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+ f} \cdot V_f$ '
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)

$$M/Vd = 4.00$$

$$M_u = 46.90894$$

$$V_u = 0.00016213$$

$$d = 0.8 \cdot h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 474729.557$$

where:

$V_{s1} = 335103.216$ is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

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

$$s/d = 0.20833333$$

$V_{s2} = 139626.34$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

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

$$s/d = 0.50$$

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 $V_f(\alpha, a_1)$, 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: $\alpha = 1 + 90^\circ = 90.00$

$V_f = \min(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:

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

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

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $V_r2 = 424229.688$
 $V_r2 = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 424229.688$
 $knl = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 46.90897$
 $Vu = 0.00016213$
 $d = 0.8 * h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$

where:

$V_{s1} = 335103.216$ is calculated for section web, with:

$d = 480.00$
 $Av = 157079.633$
 $fy = 444.4444$
 $s = 100.00$

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

$s/d = 0.20833333$

$V_{s2} = 139626.34$ is calculated for section flange, with:

$d = 200.00$
 $Av = 157079.633$
 $fy = 444.4444$
 $s = 100.00$

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

$s/d = 0.50$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

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

$E_f = 64828.00$

$fe = 0.004$, 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: 3

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

Constant Properties

Knowledge Factor, $\phi = 0.90$
 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, $f_s = f_{sm} = 444.4444$
 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, $f_s = 1.25 \cdot f_{sm} = 555.5556$
 #####
 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 = 1.26976
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i = 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

 Stepwise Properties

At local axis: 2
 EDGE -A-
 Shear Force, $V_a = 0.00016213$
 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 , $V_e/V_r = 0.66001628$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$
 with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 4.2000E+008$
 $M_{u1+} = 4.2000E+008$, 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
 $M_{u1-} = 2.3956E+008$, 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.2000E+008$$

$M_{u2+} = 4.2000E+008$, 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

$M_{u2-} = 2.3956E+008$, 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:

$$u = 1.3683079E-005$$

$$M_u = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01648022$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01648022$$

$$\phi_{cc} \text{ (5.4c), TBDY} = a_s e * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.10530374$$

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

$$\phi_{fx} = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$\phi_{fy} = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00482813$$

$$psh,x ((5.4d), \text{TBDY}) = Lstir * Astir / (Asec * s) = 0.00482813$$

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

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

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

$$psh,y ((5.4d), \text{TBDY}) = Lstir * Astir / (Asec * s) = 0.00482813$$

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

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

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

$$s = 100.00$$

$$fywe = 555.5556$$

$$fce = 20.00$$

$$\text{From } ((5.A5), \text{TBDY}), \text{TBDY: } cc = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$y1 = 0.0012967$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4504$$

$$fy1 = 311.2087$$

$$su1 = 0.00512$$

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

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

$$su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

$$\text{with } fs1 = fs = 311.2087$$

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

$$y2 = 0.0012967$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4504$$

$$fy2 = 311.2087$$

$$su2 = 0.00512$$

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

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

$$su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

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

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

$$\text{with } fs2 = fs = 311.2087$$

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

$$yv = 0.0012967$$

$$shv = 0.0044814$$

$$ftv = 373.4504$$

$$fyv = 311.2087$$

$$suv = 0.00512$$

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

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

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

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

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.

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

$$\text{with } fsv = fs = 311.2087$$

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.19518711$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09267877$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.17271953$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$c_c (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.27144518$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12888764$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.24019969$$

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

--->

$$s_u (4.8) = 0.32821401$$

$$M_u = M_{Rc} (4.15) = 4.2000E+008$$

$$u = s_u (4.1) = 1.3683079E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u1} -

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

$$u = 1.0987593E-005$$

$$M_u = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01648022$$

$$w_e ((5.4c), TBDY) = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

hmax = 600.00
From EC8 A.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

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

$ase = \text{Max}((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}} * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$
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.
 $A_{\text{conf,min}} = 122525.00$ 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$
 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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

s = 100.00
 $f_{ywe} = 555.5556$
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.0046976
c = confinement factor = 1.26976

$y1 = 0.0012967$
 $sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$

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

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

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

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

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

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

with $fs1 = fs = 311.2087$

with $Es1 = Es = 200000.00$

$y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$

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

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

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

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

For calculation of $esu2_{\text{nominal}}$ and $y2, sh2, ft2, fy2$, it is considered

characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s2} = f_s = 311.2087$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0012967$

$sh_v = 0.0044814$

$ft_v = 373.4504$

$f_{yv} = 311.2087$

$s_{uv} = 0.00512$

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

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

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

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

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

For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, 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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 311.2087$

with $E_{sv} = E_s = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03861616$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08132796$

v = $As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07196647$

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

f_{cc} (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04534935$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09550849$

v = $As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08451471$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.16341093

Mu = MRc (4.14) = 2.3956E+008

u = su (4.1) = 1.0987593E-005

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Mu2+

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

u = 1.3683079E-005

Mu = 4.2000E+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 ϕ_u : $\phi_u^* = \text{shear_factor} \cdot \text{Max}(\phi_u, \phi_c) = 0.01648022$

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

From (5.4b), TBDY: $c_u = 0.01648022$

we ((5.4c), TBDY) = $a_{se} * sh_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

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

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

$A_{conf,min} = 122525.00$ is 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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

$$l_0/l_{0u,min} = l_b/l_d = 0.30$$

$$s_u1 = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,

For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $f_{sy1} = f_{s1}/1.2$, 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.

$$\text{with } f_{s1} = f_s = 311.2087$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$s_u2 = 0.00512$$

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

and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{0u,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,

For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_{s2}/1.2$, 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.

$$\text{with } f_{s2} = f_s = 311.2087$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{uv} = 0.00512$$

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

and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{0u,min} = l_b/l_d = 0.30$$

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

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

considering characteristic value $f_{syv} = f_{sv}/1.2$, 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.

$$\text{with } f_{sv} = f_s = 311.2087$$

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19518711$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09267877$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.17271953$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$c_c (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.27144518$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.12888764$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.24019969$$

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

--->

$$s_u (4.8) = 0.32821401$$

$$\mu_u = M_{Rc} (4.15) = 4.2000E+008$$

$$u = s_u (4.1) = 1.3683079E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_2 -

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

$$\mu = 1.0987593E-005$$

$$\mu_2 = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_0 \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear_factor} * \text{Max}(\mu_2, c_0) = 0.01648022$$

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

$$\text{From (5.4b), TBDY: } \mu_2 = 0.01648022$$

$$\mu_2 \text{ (5.4c), TBDY} = a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.10530374$$

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

$$\mu_x = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$\mu_y = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.27151783$$

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

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

$A_{conf,min} = 122525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

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) = 0.00482813
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976
c = confinement factor = 1.26976

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 311.2087
with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 311.2087
with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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

with fsv = fs = 311.2087
with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616
2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796
v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04534935$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09550849$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08451471$

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

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16341093$
 $Mu = MRc (4.14) = 2.3956E+008$
 $u = su (4.1) = 1.0987593E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

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

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} * V_{Co10}$

$V_{Co10} = 424229.688$

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

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

= 1 (normal-weight concrete)

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

$M/Vd = 4.00$

$Mu = 46.90488$

$Vu = 0.00016213$

$d = 0.8*h = 480.00$

$Nu = 8883.864$

$Ag = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$

where:

$V_{s1} = 139626.34$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.4444$

$s = 100.00$

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

$s/d = 0.50$

$V_{s2} = 335103.216$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.4444$

$s = 100.00$

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

$s/d = 0.20833333$

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

$f = 0.95$, 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 $V_f(\theta, \alpha)$, 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, $V_{r2} = 424229.688$
 $V_{r2} = V_{CoI} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{CoI0}$
 $V_{CoI0} = 424229.688$
 $k_{nl} = 1$ (zero step-static loading)

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

= 1 (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 46.90486$
 $V_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
where:

$V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$

$V_{s2} = 335103.216$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$

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: 2

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

At local axis: 3

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$

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

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -6.8559E+006$

Shear Force, $V_2 = -2255.578$

Shear Force, $V_3 = 79.07961$

Axial Force, $F = -9297.478$

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 $u_{,R} = \gamma \cdot u = 0.00572018$

$u = \gamma \cdot u_p = 0.00635575$

- Calculation of γ -

$\gamma = (M_y \cdot L_s / 3) / E_{eff} = 0.00635575 ((4.29), Biskinis Phd))$

$M_y = 2.6298E+008$
 $L_s = M/V$ (with $L_s > 0.1*L$ and $L_s < 2*L$) = 3039.535
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 = 9297.478
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.6307935E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b/I_d)^{2/3}) = 248.9669$
d = 557.00
y = 0.38446193
A = 0.02986796
B = 0.01925021
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9297.478
b = 250.00
" = 0.07719928
 $y_{comp} = 8.1956051E-006$
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, $t_f = N L * t * \text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
fu = 0.01
Ef = 64828.00
Ec = 21019.039
y = 0.38314723
A = 0.02940891
B = 0.01898202
with Es = 200000.00

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

- Calculation of ϕ_p -

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

with:

- Columns not controlled by inadequate development or splicing along the clear height because $I_b/I_d \geq 1$
shear control ratio $V_y E / V_{col} I_{OE} = 0.66001628$
d = 557.00
s = 0.00
 $t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$
Av = 78.53982, is the area of every stirrup
Lstir = 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 $f = 2 \cdot t_f / b_w$ 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 = 9297.478

Ag = 237500.00

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$pl = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.02959978$

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: (a)

Calculation No. 5

column C1, Floor 1

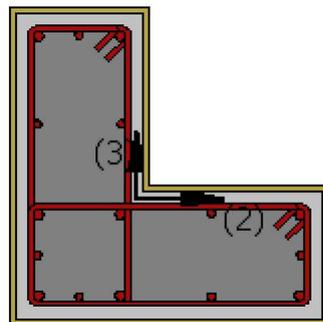
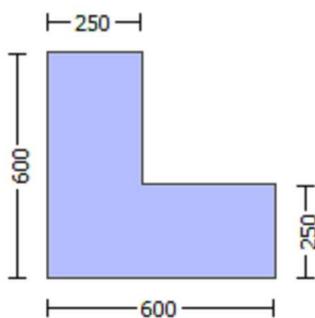
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$
 #####
 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
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

 Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -6.8559E+006$
 Shear Force, $V_a = -2255.578$
 EDGE -B-
 Bending Moment, $M_b = 86875.91$
 Shear Force, $V_b = 2255.578$
 BOTH EDGES
 Axial Force, $F = -9297.478$
 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 $V_R = \phi V_n = 396257.207$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 440285.785$
 $V_{CoI} = 440285.785$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.04030622$

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)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 86875.91$
 $V_u = 2255.578$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9297.478$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 427256.601$
 where:
 $V_{s1} = 125663.706$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 301592.895$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 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 $(\cot + \csc)\sin\alpha$ which is more a generalised expression,
 where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\alpha, a_i)$, 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: $\alpha = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 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 $\theta = 2.5284438E-005$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00062731$ ((4.29), Biskinis Phd)
 $M_y = 2.6298E+008$
 $L_s = M/V$ (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
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9297.478$
 $E_c \cdot I_g = 1.3974E+014$

 Calculation of Yielding Moment M_y

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

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

$y_{ten} = 3.6307935E-006$
 with $((10.1), ASCE 41-17) f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 248.9669$
 $d = 557.00$
 $y = 0.38446193$
 $A = 0.02986796$
 $B = 0.01925021$
 with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9297.478$
 $b = 250.00$
 $" = 0.07719928$
 $y_{comp} = 8.1956051E-006$
 with $f_c^* (12.3, (ACI 440)) = 20.42407$
 $f_c = 20.00$
 $fl = 0.62098351$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $Ag = 237500.00$
 $g = pt + pc + pv = 0.02959978$
 $rc = 40.00$
 $Ae / Ac = 0.21783041$
 Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38314723$
 $A = 0.02940891$
 $B = 0.01898202$
 with $E_s = 200000.00$

 Calculation of ratio l_b / l_d

 Inadequate Lap Length with $l_b / l_d = 0.30$

 End Of Calculation of Shear Capacity for element: column LC1 of floor 1
 At local axis: 2
 Integration Section: (b)

Calculation No. 6

column C1, Floor 1

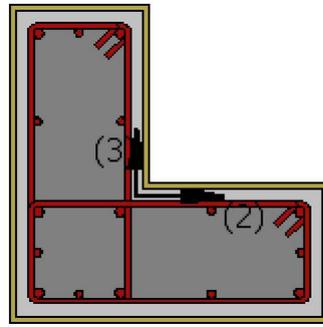
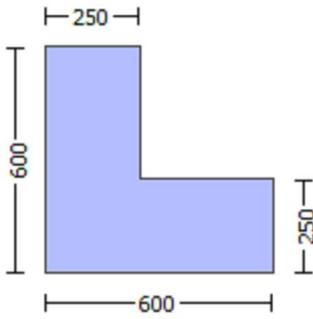
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: End

Local Axis: (2)



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

At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$
 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, $f_s = f_{sm} = 444.4444$
 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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

 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 = 1.26976
 Element Length, $L = 3000.00$

Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, $V_a = 0.00016213$
 EDGE -B-
 Shear Force, $V_b = -0.00016213$

BOTH EDGES

Axial Force, $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{,ten} = 1746.726$

-Compression: $As_{,com} = 829.3805$

-Middle: $As_{,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.66001628$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.2000E+008$

$Mu_{1+} = 4.2000E+008$, 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

$Mu_{1-} = 2.3956E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.2000E+008$

$Mu_{2+} = 4.2000E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.3956E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

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

$\phi_u = 1.3683079E-005$

$M_u = 4.2000E+008$

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 : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01648022$

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

From (5.4b), TB DY: $\phi_u = 0.01648022$

$\omega_e (5.4c, \text{TB DY}) = a_s e^* \phi_{u, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.10530374$

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

$a_f = 0.24098246$

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

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

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

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

$b_w = 250.00$

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

$\phi_y = 0.06888919$

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

$a_f = 0.24098246$

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

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

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

From EC8 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, $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

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

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

$A_{conf,min} = 122525.00$ is 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).
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00482813$

psh,x ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

s = 100.00

$f_{ywe} = 555.5556$

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976

c = confinement factor = 1.26976

$y1 = 0.0012967$

$sh1 = 0.0044814$

$ft1 = 373.4504$

$fy1 = 311.2087$

$su1 = 0.00512$

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

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

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

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

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

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

with $fs1 = fs = 311.2087$

with $Es1 = Es = 200000.00$

$y2 = 0.0012967$

$sh2 = 0.0044814$

$ft2 = 373.4504$

$fy2 = 311.2087$

$su2 = 0.00512$

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

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

$su2 = 0.4 * esu2_{nominal}$ ((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 $fs2 = fs = 311.2087$

with $Es2 = Es = 200000.00$

$yv = 0.0012967$

$shv = 0.0044814$

$ftv = 373.4504$

$fyv = 311.2087$

$suv = 0.00512$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lou, \text{min} = lb/ld = 0.30$

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

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

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

For calculation of $esuv_{\text{nominal}}$ and yv, shv, ftv, fyv , it is considered

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

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

with $fsv = fs = 311.2087$

with $Esv = Es = 200000.00$

1 = $Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.19518711$

2 = $Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.09267877$

v = $Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.17271953$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$fcc (5A.2, \text{TBDY}) = 25.3952$

$cc (5A.5, \text{TBDY}) = 0.0046976$

c = confinement factor = 1.26976

1 = $Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.27144518$

2 = $Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.12888764$

v = $Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.24019969$

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

$su (4.8) = 0.32821401$

$Mu = MRc (4.15) = 4.2000E+008$

$u = su (4.1) = 1.3683079E-005$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of $Mu1$ -

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

$u = 1.0987593E-005$

$Mu = 2.3956E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$fc = 20.00$

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

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$

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

From (5.4b), TBDY: $c_u = 0.01648022$

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

 $f_x = 0.06888919$

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

$a_f = 0.24098246$

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

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

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

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

$b_w = 250.00$

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

 $f_y = 0.06888919$

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

$a_f = 0.24098246$

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

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

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

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

$b_w = 250.00$

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

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$

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.

$A_{\text{conf,min}} = 122525.00$ 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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

Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

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

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

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

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

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

y2, sh2,ft2,fy2, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616

2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796

v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = Asl,ten/(b*d)*(fs1/fc) = 0.04534935

2 = Asl,com/(b*d)*(fs2/fc) = 0.09550849

v = Asl,mid/(b*d)*(fsv/fc) = 0.08451471

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.16341093

Mu = MRc (4.14) = 2.3956E+008

u = su (4.1) = 1.0987593E-005

Calculation of ratio lb/d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{2+}

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

$$\mu = 1.3683079E-005$$

$$\mu = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01648022$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01648022$$

$$\mu_e \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$$

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

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

$A_{conf,min} = 122525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

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

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00482813
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976
c = confinement factor = 1.26976

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19518711
2 = Asl,com/(b*d)*(fs2/fc) = 0.09267877
v = Asl,mid/(b*d)*(fsv/fc) = 0.17271953

and confined core properties:

b = 190.00

$d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.27144518$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12888764$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.24019969$
 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
 --->

$su (4.8) = 0.32821401$
 $Mu = MRc (4.15) = 4.2000E+008$
 $u = su (4.1) = 1.3683079E-005$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Mu_2 -

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.0987593E-005$
 $Mu = 2.3956E+008$

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 : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01648022$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01648022$
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$
 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, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

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

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

$A_{conf,min} = 122525.00$ is 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).

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00482813$

$psh_{,x}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00482813$

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) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00482813$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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

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

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

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

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

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

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$

$sh_2 = 0.0044814$

$ft_2 = 373.4504$

$fy_2 = 311.2087$

$su_2 = 0.00512$

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

$lo/lo_{,min} = lb/lb_{,min} = 0.30$

$su_2 = 0.4 \cdot esu_{2,nominal}$ ((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_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 311.2087$

with $Es_2 = Es = 200000.00$

$yv = 0.0012967$
 $shv = 0.0044814$
 $ftv = 373.4504$
 $fyv = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.30$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv,ftv,fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647$

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.04534935$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.09550849$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.08451471$

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

--->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16341093$
 $Mu = MRc (4.14) = 2.3956E+008$
 $u = su (4.1) = 1.0987593E-005$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Shear Strength $Vr = Min(Vr1,Vr2) = 424229.688$

Calculation of Shear Strength at edge 1, $Vr1 = 424229.688$
 $Vr1 = VCol ((10.3), ASCE 41-17) = knl * VCol0$
 $VCol0 = 424229.688$
 $knl = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc'^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 46.90894$
 $Vu = 0.00016213$
 $d = 0.8*h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 474729.557$
 where:

Vs1 = 335103.216 is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs1 is multiplied by Col1 = 1.00

$$s/d = 0.20833333$$

Vs2 = 139626.34 is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.50$$

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

f = 0.95, for fully-wrapped sections

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

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where 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: $\theta = b_1 + 90^\circ = 90.00$

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

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

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

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

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

$$b_w = 250.00$$

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

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

$$V_{Col0} = 424229.688$$

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

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

$\lambda = 1$ (normal-weight concrete)

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

$$M/Vd = 4.00$$

$$M_u = 46.90897$$

$$V_u = 0.00016213$$

$$d = 0.8 \cdot h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$

where:

Vs1 = 335103.216 is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs1 is multiplied by Col1 = 1.00

$$s/d = 0.20833333$$

Vs2 = 139626.34 is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.50$$

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 $V_f(\theta, \alpha)$, 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

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

$b_w = 250.00$

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

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 = 1.26976

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $\text{NoDir} = 1$

Fiber orientations, $\theta_i = 0.00^\circ$

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: $As_t = 0.00$

-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: $As_{c,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.66001628$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.2000E+008$
 $Mu_{1+} = 4.2000E+008$, 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
 $Mu_{1-} = 2.3956E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.2000E+008$
 $Mu_{2+} = 4.2000E+008$, 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
 $Mu_{2-} = 2.3956E+008$, 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:

$\phi_u = 1.3683079E-005$

$M_u = 4.2000E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01648022$

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

From (5.4b), TBDY: $\phi_{cu} = 0.01648022$

where ϕ_{cu} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.10530374$

where $\phi_{fx} = \alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.06888919$

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

$\alpha_{se} = 0.24098246$

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), $\phi_{fy} = 2t_f/b_w = 0.008128$

$b_w = 250.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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

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

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

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

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

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

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$

$sh_2 = 0.0044814$

$ft_2 = 373.4504$

$fy_2 = 311.2087$

$su_2 = 0.00512$

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

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

$$s_u2 = 0.4 * e_{su2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2_nominal} = 0.08$,

For calculation of $e_{su2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

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

$$\text{with } f_{s2} = f_s = 311.2087$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{uv} = 0.00512$$

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

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

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

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

considering characteristic value $f_{syv} = f_{sv}/1.2$, 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.

$$\text{with } f_{sv} = f_s = 311.2087$$

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

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19518711$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09267877$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.17271953$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$cc (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.27144518$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.12888764$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.24019969$$

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

--->

$$s_u (4.8) = 0.32821401$$

$$M_u = M_{Rc} (4.15) = 4.2000E+008$$

$$u = s_u (4.1) = 1.3683079E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u1} -

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

$$u = 1.0987593E-005$$

$$M_u = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01648022$$

$$w_e ((5.4c), TBDY) = a_s e^* s h, \min * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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., 10.11061/(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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

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

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

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

$$p_{sh,y} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

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

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

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

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.0046976$$

$c = \text{confinement factor} = 1.26976$
 $y1 = 0.0012967$
 $sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.30$
 $su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs1 = fs = 311.2087$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.30$
 $su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs2 = fs = 311.2087$
 with $Es2 = Es = 200000.00$
 $yv = 0.0012967$
 $shv = 0.0044814$
 $ftv = 373.4504$
 $fyv = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.30$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.03861616$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.08132796$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.07196647$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.04534935$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.09550849$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.08451471$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.16341093$$

$$M_u = M_{Rc}(4.14) = 2.3956E+008$$

$$u = s_u(4.1) = 1.0987593E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u2+}

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

$$u = 1.3683079E-005$$

$$M_u = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01648022$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01648022$$

$$\phi_{we}((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.10530374$$

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

$$\phi_x = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$\phi_y = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.27151783$$

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

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

Aconf,min = 122525.00 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) = 0.00482813

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00482813
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) = 0.00482813
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00

fywe = 555.5556

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976

c = confinement factor = 1.26976

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

su1 = 0.00512

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

lo/lou,min = lb/l_d = 0.30

su1 = 0.4*esu1_nominal ((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 = fs/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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

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

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

su2 = 0.4*esu2_nominal ((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 = fs/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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

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

lo/lou,min = lb/l_d = 0.30

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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 $f_{sv} = f_s = 311.2087$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.19518711$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09267877$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.17271953$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 25.3952$

$cc (5A.5, TBDY) = 0.0046976$

$c = \text{confinement factor} = 1.26976$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.27144518$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12888764$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.24019969$

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

--->

$su (4.8) = 0.32821401$

$Mu = MRc (4.15) = 4.2000E+008$

$u = su (4.1) = 1.3683079E-005$

Calculation of ratio lb/d

Inadequate Lap Length with $lb/d = 0.30$

Calculation of Mu_2 -

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

$u = 1.0987593E-005$

$Mu = 2.3956E+008$

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 : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01648022$

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

From (5.4b), TBDY: $cu = 0.01648022$

$w_e ((5.4c), TBDY) = a_{se} \cdot sh_{,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$

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), $f_{fe} = 703.4155$

$f_y = 0.06888919$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.27151783$

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

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

$A_{conf,min} = 122525.00$ is 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).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00482813$

psh_x ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

c = confinement factor = 1.26976

$y1 = 0.0012967$

$sh1 = 0.0044814$

$ft1 = 373.4504$

$fy1 = 311.2087$

$su1 = 0.00512$

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

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

$su1 = 0.4*es_{u1,nominal}$ ((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 $\text{Min}(1, 1.25*(l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y2 = 0.0012967$

$sh2 = 0.0044814$

$ft2 = 373.4504$

$fy2 = 311.2087$

$su2 = 0.00512$

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

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

$$s_u2 = 0.4 * e_{s_u2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_u2,nominal} = 0.08$,

For calculation of $e_{s_u2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{s_y2} = f_{s_2}/1.2$, 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.

$$\text{with } f_{s_2} = f_s = 311.2087$$

$$\text{with } E_{s_2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{u_v} = 0.00512$$

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

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

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

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

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

For calculation of $e_{s_{u_v},nominal}$ and y_v, sh_v, ft_v, fy_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, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s_v} = f_s = 311.2087$$

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

$$1 = A_{s_l,ten}/(b*d)*(f_{s_1}/f_c) = 0.03861616$$

$$2 = A_{s_l,com}/(b*d)*(f_{s_2}/f_c) = 0.08132796$$

$$v = A_{s_l,mid}/(b*d)*(f_{s_v}/f_c) = 0.07196647$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$c_c (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{s_l,ten}/(b*d)*(f_{s_1}/f_c) = 0.04534935$$

$$2 = A_{s_l,com}/(b*d)*(f_{s_2}/f_c) = 0.09550849$$

$$v = A_{s_l,mid}/(b*d)*(f_{s_v}/f_c) = 0.08451471$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16341093$$

$$M_u = M_{Rc} (4.14) = 2.3956E+008$$

$$u = s_u (4.1) = 1.0987593E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

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

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} * V_{Co1}$$

$$V_{Co1} = 424229.688$$

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

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

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

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

$M/Vd = 4.00$
 $\mu_u = 46.90488$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:
 $V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 335103.216$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, 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: $\theta = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 424229.688$
 $k_{nl} = 1$ (zero step-static loading)

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

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 46.90486$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:
 $V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 335103.216$ is calculated for section flange, with:

$d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
Vs2 is multiplied by Col2 = 1.00
 $s/d = 0.20833333$
 $V_f((11-3)-(11.4), \text{ACI 440}) = 293495.545$
 $f = 0.95$, 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 a is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

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, $\phi = 0.90$
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, $f_s = f_{sm} = 444.4444$
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
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_b/l_d = 0.30$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $\text{NoDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$

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

Stepwise Properties

Bending Moment, M = -65334.277
Shear Force, V2 = 2255.578
Shear Force, V3 = -79.07961
Axial Force, F = -9297.478
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 $u,R = * u = 0.00155482$
 $u = y + p = 0.00172757$

- Calculation of y -

$y = (My * Ls / 3) / Eleff = 0.00172757$ ((4.29), Biskinis Phd)
My = 2.6298E+008
Ls = M/V (with Ls > 0.1*L and Ls < 2*L) = 826.1837
From table 10.5, ASCE 41_17: Eleff = factor * Ec * Ig = 4.1921E+013
factor = 0.30
Ag = 237500.00
fc' = 20.00
N = 9297.478
Ec * Ig = 1.3974E+014

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.6307935E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 248.9669$
d = 557.00
y = 0.38446193
A = 0.02986796
B = 0.01925021
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9297.478
b = 250.00
" = 0.07719928
 $y_{comp} = 8.1956051E-006$
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, $t_f = NL \cdot t \cdot \cos(\beta_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38314723$
 $A = 0.02940891$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

- 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 $V_y E / V_c \rho I E = 0.66001628$

$d = 557.00$

$s = 0.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = A_v \cdot L_{stir} / (A_g \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ 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.

$N_{UD} = 9297.478$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

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

At local axis: 2

Integration Section: (b)

Calculation No. 7

column C1, Floor 1

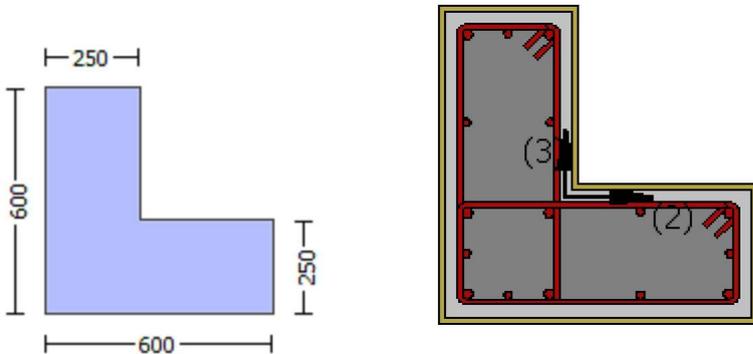
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



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

At local axis: 3

Integration Section: (b)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$

#####

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

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -171049.041$
Shear Force, $V_a = 79.07961$
EDGE -B-
Bending Moment, $M_b = -65334.277$
Shear Force, $V_b = -79.07961$
BOTH EDGES
Axial Force, $F = -9297.478$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_{lt} = 0.00$
-Compression: $As_{lc} = 4121.77$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 1746.726$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 1545.664$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 396257.207$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI0} = 440285.785$
 $V_{CoI} = 440285.785$
 $k_n = 1.00$
 $displacement_ductility_demand = 1.2058309E-005$

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

 $\phi = 1$ (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 65334.277$
 $V_u = 79.07961$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9297.478$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 427256.601$
where:
 $V_{s1} = 301592.895$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.20833333$
 $V_{s2} = 125663.706$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 V_f ((11-3)-(11.4), ACI 440) = 293495.545
 $\phi = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin^2 \theta + \cos^2 \theta$ is replaced with $(\cot^2 \theta + \csc^2 \theta) \sin^2 \theta$ which is more a generalised expression,

where 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: $\theta = b1 + 90^\circ = 90.00$

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 318865.838$

$b_w = 250.00$

displacement ductility demand is calculated as δ / y

- Calculation of δ / y for END B -

for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 2.0831619E-008$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00172757$ ((4.29), Biskinis Phd)

$M_y = 2.6298E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 826.1837

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

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9297.478$

$E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

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

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

$y_{ten} = 3.6307935E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 248.9669$

$d = 557.00$

$y = 0.38446193$

$A = 0.02986796$

$B = 0.01925021$

with $p_t = 0.01254381$

$p_c = 0.00595605$

$p_v = 0.01109992$

$N = 9297.478$

$b = 250.00$

$\alpha = 0.07719928$

$y_{comp} = 8.1956051E-006$

with f_c^* (12.3, (ACI 440)) = 20.42407

$f_c = 20.00$

$f_l = 0.62098351$

$b = b_{max} = 600.00$

$h = h_{max} = 600.00$

$A_g = 237500.00$

$g = p_t + p_c + p_v = 0.02959978$

$r_c = 40.00$

$A_e / A_c = 0.21783041$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.38314723$

A = 0.02940891
B = 0.01898202
with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

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

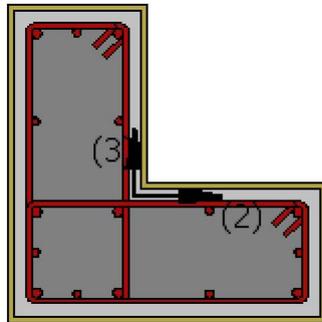
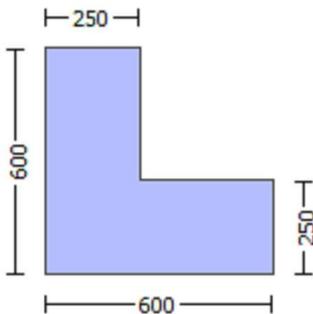
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

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 = 1.26976

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00016213$

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 , $V_e/V_r = 0.66001628$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$

with

$M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 4.2000E+008$

$Mu_{1+} = 4.2000E+008$, 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

$Mu_{1-} = 2.3956E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 4.2000E+008$

$Mu_{2+} = 4.2000E+008$, 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

$Mu_{2-} = 2.3956E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

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

$$\mu = 1.3683079E-005$$

$$Mu = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00318999$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01648022$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01648022$$

$$\mu_e \text{ ((5.4c), TBDY)} = a_s e^* \text{ sh, min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

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

$$a_f = 0.24098246$$

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

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

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

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$p_{sh,\text{min}} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

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

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

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

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00

fywe = 555.5556

fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.0046976

c = confinement factor = 1.26976

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

su1 = 0.00512

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

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

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

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

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

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

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19518711

2 = Asl,com/(b*d)*(fs2/fc) = 0.09267877

v = Asl,mid/(b*d)*(fsv/fc) = 0.17271953

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.27144518$$

$$2 = A_{s2,com}/(b*d)*(f_{s2}/f_c) = 0.12888764$$

$$v = A_{s,mid}/(b*d)*(f_{sv}/f_c) = 0.24019969$$

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) = 0.32821401
 $M_u = M_{Rc}$ (4.15) = 4.2000E+008
 $u = \mu_u$ (4.1) = 1.3683079E-005

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u1} -

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

$$u = 1.0987593E-005$$

$$M_u = 2.3956E+008$$

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
Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01648022$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_u = 0.01648022$
 μ_{we} ((5.4c), TBDY) = $a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$
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), $f_{fe} = 703.4155$

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

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

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$$

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

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

$A_{conf,min} = 122525.00$ is 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).
 $psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00482813$

$$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

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

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

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

$$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

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

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

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

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

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

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

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

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.

$$\text{with } fs_1 = fs = 311.2087$$

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

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$su_2 = 0.00512$$

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

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

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

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

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

y_2 , sh_2 , ft_2 , fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 311.2087$$

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

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616

2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796

v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = Asl,ten/(b*d)*(fs1/fc) = 0.04534935

2 = Asl,com/(b*d)*(fs2/fc) = 0.09550849

v = Asl,mid/(b*d)*(fsv/fc) = 0.08451471

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.16341093

Mu = MRc (4.14) = 2.3956E+008

u = su (4.1) = 1.0987593E-005

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2+

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

u = 1.3683079E-005

Mu = 4.2000E+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* = shear_factor * Max(cu, cc) = 0.01648022

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

From (5.4b), TBDY: cu = 0.01648022

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.10530374

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

$b_{max} = 600.00$

$h_{max} = 600.00$

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

$b_w = 250.00$

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

$f_y = 0.06888919$

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

$af = 0.24098246$

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), $pf = 2t_f/b_w = 0.008128$

$b_w = 250.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}), 0) = 0.27151783$

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

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

$A_{conf,min} = 122525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

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

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

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

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

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

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

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

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

lo/lou,min = lb/ld = 0.30

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

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

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

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

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19518711

2 = Asl,com/(b*d)*(fs2/fc) = 0.09267877

v = Asl,mid/(b*d)*(fsv/fc) = 0.17271953

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = Asl,ten/(b*d)*(fs1/fc) = 0.27144518

2 = Asl,com/(b*d)*(fs2/fc) = 0.12888764

v = Asl,mid/(b*d)*(fsv/fc) = 0.24019969

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) = 0.32821401

Mu = MRc (4.15) = 4.2000E+008

u = su (4.1) = 1.3683079E-005

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu2-

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

$$u = 1.0987593E-005$$

$$Mu = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01648022$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01648022$$

$$\phi_{we} \text{ ((5.4c), TBDY) } = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.10530374$$

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

$$\phi_{fx} = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$\phi_{fy} = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$\phi_{\text{psh,min}} = \text{Min}(\phi_{\text{psh,x}}, \phi_{\text{psh,y}}) = 0.00482813$$

$$\phi_{\text{psh,x}} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

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

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

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

$$\phi_{\text{psh,y}} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

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

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

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

$s = 100.00$
 $fy_{we} = 555.5556$
 $f_{ce} = 20.00$
 From ((5.A.5), TBDY), TBDY: $cc = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $y_1 = 0.0012967$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4504$
 $fy_1 = 311.2087$
 $su_1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/d = 0.30$
 $su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_1 \text{ nominal} = 0.08$,
 For calculation of $esu_1 \text{ nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 311.2087$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.0012967$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4504$
 $fy_2 = 311.2087$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 0.30$
 $su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_2 \text{ nominal} = 0.08$,
 For calculation of $esu_2 \text{ nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 311.2087$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/d = 0.30$
 $suv = 0.4 * esuv \text{ nominal ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esuv \text{ nominal} = 0.08$,
 considering characteristic value $fsyv = fs_v/1.2$, from table 5.1, TBDY
 For calculation of $esuv \text{ nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fs_v/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_v = fs = 311.2087$
 with $Es_v = Es = 200000.00$
 $1 = Asl, \text{ten}/(b*d) * (fs_1/fc) = 0.03861616$
 $2 = Asl, \text{com}/(b*d) * (fs_2/fc) = 0.08132796$
 $v = Asl, \text{mid}/(b*d) * (fs_v/fc) = 0.07196647$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} \text{ (5A.2, TBDY)} = 25.3952$
 $cc \text{ (5A.5, TBDY)} = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl, \text{ten}/(b*d) * (fs_1/fc) = 0.04534935$
 $2 = Asl, \text{com}/(b*d) * (fs_2/fc) = 0.09550849$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08451471$$

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

--->

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

--->

$$s_u(4.9) = 0.16341093$$

$$M_u = M_{Rc}(4.14) = 2.3956E+008$$

$$u = s_u(4.1) = 1.0987593E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

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

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

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

$$V_{Col0} = 424229.688$$

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

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+ f} \cdot V_f$ '
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)

$$M/Vd = 4.00$$

$$M_u = 46.90894$$

$$V_u = 0.00016213$$

$$d = 0.8 \cdot h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 474729.557$$

where:

$V_{s1} = 335103.216$ is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

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

$$s/d = 0.20833333$$

$V_{s2} = 139626.34$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

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

$$s/d = 0.50$$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

$V_f = \min(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 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, $Vr2 = 424229.688$
 $Vr2 = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 424229.688$
 $knl = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 46.90897$
 $Vu = 0.00016213$
 $d = 0.8 * h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$

where:

$V_{s1} = 335103.216$ is calculated for section web, with:

$d = 480.00$
 $Av = 157079.633$
 $fy = 444.4444$
 $s = 100.00$

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

$s/d = 0.20833333$

$V_{s2} = 139626.34$ is calculated for section flange, with:

$d = 200.00$
 $Av = 157079.633$
 $fy = 444.4444$
 $s = 100.00$

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

$s/d = 0.50$

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

$f = 0.95$, 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: 3

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

Constant Properties

Knowledge Factor, $\phi = 0.90$
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, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

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 = 1.26976
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 0.00016213$
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 , $V_e/V_r = 0.66001628$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$
with
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 4.2000E+008$
 $M_{u1+} = 4.2000E+008$, 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
 $M_{u1-} = 2.3956E+008$, 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.2000E+008$$

$M_{u2+} = 4.2000E+008$, 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

$M_{u2-} = 2.3956E+008$, 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:

$$\phi_u = 1.3683079E-005$$

$$M_u = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01648022$$

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

$$\text{From (5.4b), TB DY: } \phi_{cu} = 0.01648022$$

$$\phi_{ve} \text{ ((5.4c), TB DY) } = a_{se} * \phi_{h, \min} * f_{yve} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.10530374$$

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

$$\phi_{fx} = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$\phi_{fy} = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00482813$$

$$psh,x ((5.4d), \text{TBDY}) = Lstir * Astir / (Asec * s) = 0.00482813$$

$$Lstir (\text{Length of stirrups along Y}) = 1460.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 237500.00$$

$$psh,y ((5.4d), \text{TBDY}) = Lstir * Astir / (Asec * s) = 0.00482813$$

$$Lstir (\text{Length of stirrups along X}) = 1460.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 237500.00$$

$$s = 100.00$$

$$fywe = 555.5556$$

$$fce = 20.00$$

$$\text{From } ((5.A5), \text{TBDY}), \text{TBDY: } cc = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$y1 = 0.0012967$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4504$$

$$fy1 = 311.2087$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$$

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.

$$\text{with } fs1 = fs = 311.2087$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0012967$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4504$$

$$fy2 = 311.2087$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$$

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.

$$\text{with } fs2 = fs = 311.2087$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0012967$$

$$shv = 0.0044814$$

$$ftv = 373.4504$$

$$fyv = 311.2087$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$$

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.

$$\text{with } fsv = fs = 311.2087$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.19518711$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09267877$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.17271953$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$c_c (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.27144518$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12888764$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.24019969$$

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

--->

$$s_u (4.8) = 0.32821401$$

$$M_u = M_{Rc} (4.15) = 4.2000E+008$$

$$u = s_u (4.1) = 1.3683079E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0987593E-005$$

$$M_u = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01648022$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 600.00$$

hmax = 600.00
From EC8 A.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase = \text{Max}((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}} * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$
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.
 $A_{\text{conf,min}} = 122525.00$ 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$
 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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

s = 100.00
 $f_{ywe} = 555.5556$
fce = 20.00
From ((5.A5), TBDY), TBDY: $cc = 0.0046976$
c = confinement factor = 1.26976

$y1 = 0.0012967$
 $sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 311.2087$

with $Es1 = Es = 200000.00$

$y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$su2 = 0.4 * esu2_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and $y2, sh2, ft2, fy2$, it is considered

characteristic value $f_{s2} = f_s/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s2} = f_s = 311.2087$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0012967$

$sh_v = 0.0044814$

$ft_v = 373.4504$

$f_{yv} = 311.2087$

$s_{uv} = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$s_{uv} = 0.4 \cdot e_{suv,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, f_{yv} , it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 311.2087$

with $E_{sv} = E_s = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03861616$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08132796$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07196647$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 25.3952$

$cc (5A.5, TBDY) = 0.0046976$

$c =$ confinement factor = 1.26976

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04534935$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09550849$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08451471$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$s_u (4.9) = 0.16341093$

$M_u = MR_c (4.14) = 2.3956E+008$

$u = s_u (4.1) = 1.0987593E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u2+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$u = 1.3683079E-005$

$M_u = 4.2000E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

$cc (5A.5, TBDY) = 0.002$

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} \cdot \text{Max}(\phi_u, cc) = 0.01648022$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01648022$

where ((5.4c), TBDY) = $a_{se} * sh_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$

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, $t_f = NL * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ 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.

$A_{conf,min} = 122525.00$ is 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{0u,min} = l_b/l_d = 0.30$$

$$s_u1 = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,

For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $f_{sy1} = f_{s1}/1.2$, 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.

$$\text{with } f_{s1} = f_s = 311.2087$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$s_u2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{0u,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,

For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_{s2}/1.2$, 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.

$$\text{with } f_{s2} = f_s = 311.2087$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{uv} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{0u,min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, 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.

$$\text{with } f_{sv} = f_s = 311.2087$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19518711$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09267877$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.17271953$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$c_c (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.27144518$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.12888764$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.24019969$$

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

--->

$$s_u (4.8) = 0.32821401$$

$$\mu_u = M_{Rc} (4.15) = 4.2000E+008$$

$$u = s_u (4.1) = 1.3683079E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.0987593E-005$$

$$\mu_2 = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_0 \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear_factor} * \text{Max}(\mu_2, c_0) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_2 = 0.01648022$$

$$\mu_2 \text{ (5.4c), TBDY} = a_{se} * \mu_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.10530374$$

where $\mu_f = a_f * \mu_{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{fx} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{pf} = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$\mu_{fy} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{pf} = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.27151783$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 122525.00$ is 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).

$$\mu_{sh,min} = \text{Min}(\mu_{sh,x}, \mu_{sh,y}) = 0.00482813$$

$$\mu_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

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) = 0.00482813
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976
c = confinement factor = 1.26976

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616

2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796

v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04534935$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09550849$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08451471$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16341093$
 $Mu = MRc (4.14) = 2.3956E+008$
 $u = su (4.1) = 1.0987593E-005$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$
 $V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 424229.688$
 $knl = 1$ (zero step-static loading)

 NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
 where Vf is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 46.90488$
 $Vu = 0.00016213$
 $d = 0.8*h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:
 $V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 335103.216$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, 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 $V_f(\theta, \alpha)$, 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, $V_{r2} = 424229.688$
 $V_{r2} = V_{CoI} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{CoI0}$
 $V_{CoI0} = 424229.688$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+ f \cdot V_f}$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 46.90486$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
where:

$V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$

$V_{s2} = 335103.216$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$

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 $(\cot \theta + \csc \theta) \sin a$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$

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

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 86875.91$

Shear Force, $V_2 = 2255.578$

Shear Force, $V_3 = -79.07961$

Axial Force, $F = -9297.478$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1746.726$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \gamma \cdot u = 0.00056458$

$u = \gamma \cdot u_p = 0.00062731$

- Calculation of γ -

$\gamma = (M_y \cdot L_s / 3) / E_{eff} = 0.00062731$ ((4.29), Biskinis Phd))

$M_y = 2.6298E+008$
 $L_s = M/V$ (with $L_s > 0.1*L$ and $L_s < 2*L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9297.478$
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to Annex 7 -

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.6307935E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b/I_d)^{2/3}) = 248.9669$
 $d = 557.00$
 $y = 0.38446193$
 $A = 0.02986796$
 $B = 0.01925021$
with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9297.478$
 $b = 250.00$
 $\rho = 0.07719928$
 $y_{comp} = 8.1956051E-006$
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, $t_f = N L * t * \text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38314723$
 $A = 0.02940891$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

- 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 $I_b/I_d \geq 1$

shear control ratio $V_y E / V_{col} I_{OE} = 0.66001628$

$d = 557.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, 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 $f = 2 \cdot t_f / b_w$ 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 = 9297.478

Ag = 237500.00

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$pl = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.02959978$

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)

Calculation No. 9

column C1, Floor 1

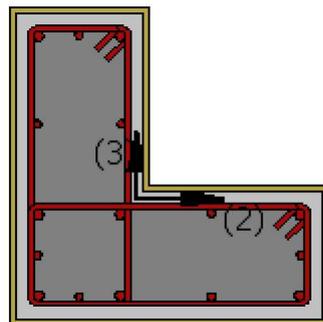
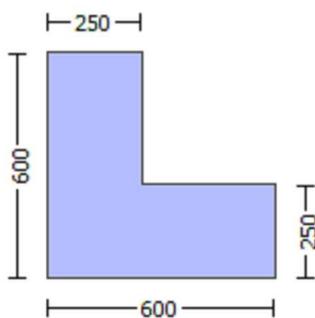
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

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, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$
 #####
 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
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

 Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -8.5372E+006$
 Shear Force, $V_a = -2808.718$
 EDGE -B-
 Bending Moment, $M_b = 108192.18$
 Shear Force, $V_b = 2808.718$
 BOTH EDGES
 Axial Force, $F = -9398.91$
 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 $V_R = \phi V_n = 341627.22$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 379585.80$
 $V_{CoI} = 379585.80$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.01315402$

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)
 $M/Vd = 4.00$
 $M_u = 8.5372E+006$
 $V_u = 2808.718$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9398.91$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 427256.601$
 where:
 $V_{s1} = 125663.706$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 301592.895$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 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 $(\cot + \csc)\sin\alpha$ which is more a generalised expression,
 where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\alpha, a_i)$, 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: $\alpha = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 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 $\theta = 8.3610130E-005$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00635624$ ((4.29), Biskinis Phd)
 $M_y = 2.6300E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3039.539
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$
 $\text{factor} = 0.30$
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9398.91$
 $E_c \cdot I_g = 1.3974E+014$

 Calculation of Yielding Moment M_y

 Calculation of δ and M_y according to Annex 7 -

 $y = \text{Min}(\delta_{ten}, \delta_{com})$

y_ten = 3.6309447E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^ 2/3) = 248.9669
d = 557.00
y = 0.38448755
A = 0.02987089
B = 0.01925313
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9398.91
b = 250.00
" = 0.07719928
y_comp = 8.1953602E-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 = 0.38315868
A = 0.02940683
B = 0.01898202
with Es = 200000.00

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

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

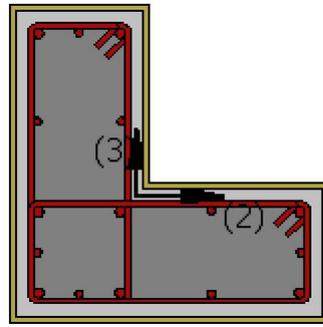
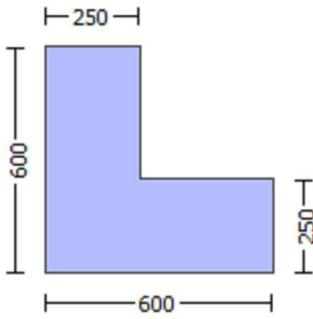
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

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: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$
 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, $f_s = f_{sm} = 444.4444$
 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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

 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 = 1.26976
 Element Length, $L = 3000.00$

Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, $V_a = 0.00016213$
 EDGE -B-
 Shear Force, $V_b = -0.00016213$

BOTH EDGES

Axial Force, $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{,ten} = 1746.726$

-Compression: $As_{,com} = 829.3805$

-Middle: $As_{,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.66001628$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.2000E+008$

$Mu_{1+} = 4.2000E+008$, 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

$Mu_{1-} = 2.3956E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.2000E+008$

$Mu_{2+} = 4.2000E+008$, 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

$Mu_{2-} = 2.3956E+008$, 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:

$\phi_u = 1.3683079E-005$

$M_u = 4.2000E+008$

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 : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01648022$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY: $\phi_u = 0.01648022$

where $\phi_u (5.4c, \text{TB DY}) = a_s e^* \phi_{u, \text{min}} * f_{y, \text{we}} / f_{c, \text{e}} + \text{Min}(\phi_x, \phi_y) = 0.10530374$

where $\phi = a_f * \phi_{f, \text{eff}} / f_{c, \text{e}}$ 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 = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 57233.333$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f, \text{eff}} = 703.4155$

$\phi_y = 0.06888919$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.24098246$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 0.00$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

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, $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$

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.

$A_{\text{conf,min}} = 122525.00$ 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 $b^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$

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) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

s = 100.00

$f_{ywe} = 555.5556$

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976

c = confinement factor = 1.26976

$y_1 = 0.0012967$

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

su1 = $0.4 * e_{su1_nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $e_{su1_nominal} = 0.08$,

For calculation of $e_{su1_nominal}$ and y_1 , sh1, ft1, fy1, it is considered characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

y_1 , sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s1} = f_s = 311.2087$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.0012967$

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

su2 = $0.4 * e_{su2_nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $e_{su2_nominal} = 0.08$,

For calculation of $e_{su2_nominal}$ and y_2 , sh2, ft2, fy2, it is considered characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 311.2087$

with $Es2 = Es = 200000.00$

$yv = 0.0012967$

$shv = 0.0044814$

$ftv = 373.4504$

$fyv = 311.2087$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lou, \text{min} = lb/ld = 0.30$

$suv = 0.4 \cdot esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: $esuv_{\text{nominal}} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_{\text{nominal}}$ and yv, shv, ftv, fyv , it is considered

characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 311.2087$

with $Esv = Es = 200000.00$

1 = $Asl, \text{ten}/(b \cdot d) \cdot (fs1/fc) = 0.19518711$

2 = $Asl, \text{com}/(b \cdot d) \cdot (fs2/fc) = 0.09267877$

$v = Asl, \text{mid}/(b \cdot d) \cdot (fsv/fc) = 0.17271953$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, \text{TBDY}) = 25.3952$

$cc (5A.5, \text{TBDY}) = 0.0046976$

$c = \text{confinement factor} = 1.26976$

1 = $Asl, \text{ten}/(b \cdot d) \cdot (fs1/fc) = 0.27144518$

2 = $Asl, \text{com}/(b \cdot d) \cdot (fs2/fc) = 0.12888764$

$v = Asl, \text{mid}/(b \cdot d) \cdot (fsv/fc) = 0.24019969$

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

$su (4.8) = 0.32821401$

$Mu = MRc (4.15) = 4.2000E+008$

$u = su (4.1) = 1.3683079E-005$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of $Mu1$ -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 1.0987593E-005$

$Mu = 2.3956E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$fc = 20.00$

$co (5A.5, \text{TBDY}) = 0.002$

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01648022$

w_e ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$

where $f = af * pf * ff_e / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.24098246$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff_e = 703.4155$

 $f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.24098246$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff_e = 703.4155$

 $R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 122525.00$ is 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 100.00$

$fy_{we} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

c = confinement factor = 1.26976

$y1 = 0.0012967$

$sh1 = 0.0044814$

$ft1 = 373.4504$

$fy1 = 311.2087$

$su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616

2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796

v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = Asl,ten/(b*d)*(fs1/fc) = 0.04534935

2 = Asl,com/(b*d)*(fs2/fc) = 0.09550849

v = Asl,mid/(b*d)*(fsv/fc) = 0.08451471

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vsy2 - LHS eq.(4.5) is satisfied

su (4.9) = 0.16341093

Mu = MRc (4.14) = 2.3956E+008

u = su (4.1) = 1.0987593E-005

Calculation of ratio lb/d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.3683079E-005$$

$$\mu_u = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.01648022$$

$$\mu_{ue} \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 122525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00482813
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976
c = confinement factor = 1.26976

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19518711
2 = Asl,com/(b*d)*(fs2/fc) = 0.09267877
v = Asl,mid/(b*d)*(fsv/fc) = 0.17271953

and confined core properties:

b = 190.00

$d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.27144518$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12888764$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.24019969$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
 --->

$\mu_u (4.8) = 0.32821401$
 $M_u = M_{Rc} (4.15) = 4.2000E+008$
 $u = \mu_u (4.1) = 1.3683079E-005$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of μ_{u2} -

 Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.0987593E-005$
 $M_u = 2.3956E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$
 $f_c = 20.00$
 $cc (5A.5, TBDY) = 0.002$
 Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, cc) = 0.01648022$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\mu_u = 0.01648022$
 $w_e ((5.4c), TBDY) = a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$
 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), $f_{f,e} = 703.4155$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL \cdot t \cdot \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) \cdot (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$su_1 = 0.4 \cdot esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 311.2087$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$su_2 = 0.4 \cdot esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{2,nominal} = 0.08,$$

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_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 311.2087$$

$$\text{with } Es_2 = Es = 200000.00$$

$y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $su_v = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.30$
 $su_v = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fs_v = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_v = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.03861616$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.08132796$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.07196647$

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.04534935$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.09550849$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08451471$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16341093$
 $Mu = MRc (4.14) = 2.3956E+008$
 $u = su (4.1) = 1.0987593E-005$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$
 $V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = knl * V_{Co10}$
 $V_{Co10} = 424229.688$
 $knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
 where Vf is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc'^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 46.90894$
 $Vu = 0.00016213$
 $d = 0.8 * h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:

Vs1 = 335103.216 is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs1 is multiplied by Col1 = 1.00

$$s/d = 0.20833333$$

Vs2 = 139626.34 is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.50$$

Vf ((11-3)-(11.4), ACI 440) = 293495.545

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where 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: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

f_{fe} ((11-5), ACI 440) = 259.312

$$E_f = 64828.00$$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$

$$V_{Col0} = 424229.688$$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf' where Vf 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)

$$M/Vd = 4.00$$

$$M_u = 46.90897$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$

where:

Vs1 = 335103.216 is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs1 is multiplied by Col1 = 1.00

$$s/d = 0.20833333$$

Vs2 = 139626.34 is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.50$$

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 $V_f(\theta, \alpha)$, 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (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: rdlcs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

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 = 1.26976

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{o,min} = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $\text{NoDir} = 1$

Fiber orientations, $\theta_i = 0.00^\circ$

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: $As_t = 0.00$

-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: $As_{c,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.66001628$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 4.2000E+008$

$M_{u1+} = 4.2000E+008$, 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

$M_{u1-} = 2.3956E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.2000E+008$

$M_{u2+} = 4.2000E+008$, 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

$M_{u2-} = 2.3956E+008$, 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:

$\phi_u = 1.3683079E-005$

$M_u = 4.2000E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01648022$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_{cu} = 0.01648022$

ω_e ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

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, $t_f = NL * t * \cos(\beta_1) = 1.016$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

From ((5.A5), TBDY), TBDY: $c_c = 0.0046976$

c = confinement factor = 1.26976

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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 $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{su2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2_nominal} = 0.08$,

For calculation of $e_{su2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 311.2087$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{uv} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, 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.

$$\text{with } f_{sv} = f_s = 311.2087$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19518711$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09267877$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.17271953$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$cc (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.27144518$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.12888764$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.24019969$$

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

--->

$$s_u (4.8) = 0.32821401$$

$$M_u = M_{Rc} (4.15) = 4.2000E+008$$

$$u = s_u (4.1) = 1.3683079E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0987593E-005$$

$$M_u = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01648022$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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., 10.11061/(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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$p_{sh, \min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} (\text{Length of stirrups along } Y) = 1460.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} (\text{Length of stirrups along } X) = 1460.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.0046976$$

$c = \text{confinement factor} = 1.26976$
 $y1 = 0.0012967$
 $sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.30$
 $su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fs1 = fs = 311.2087$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 0.30$
 $su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fs2 = fs = 311.2087$
 with $Es2 = Es = 200000.00$
 $yv = 0.0012967$
 $shv = 0.0044814$
 $ftv = 373.4504$
 $fyv = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.30$
 $suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.03861616$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.08132796$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.07196647$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 25.3952$
 $cc (5A.5, \text{TBDY}) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.04534935$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.09550849$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.08451471$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.16341093$$

$$M_u = M_{Rc}(4.14) = 2.3956E+008$$

$$u = s_u(4.1) = 1.0987593E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of $M_u/2+$

Calculation of ultimate curvature κ_u according to 4.1, Biskinis/Fardis 2013:

$$\kappa_u = 1.3683079E-005$$

$$M_u = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \kappa_u: \kappa_u^* = \text{shear_factor} * \text{Max}(\kappa_u, \kappa_c) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \kappa_u = 0.01648022$$

$$\omega_e(5.4c, TBDY) = a_s e^* s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,5} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$$

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.

Aconf,min = 122525.00 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) = 0.00482813

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00482813
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) = 0.00482813
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00

fywe = 555.5556

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976

c = confinement factor = 1.26976

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/l_d = 0.30

su1 = 0.4*esu1_nominal ((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 = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/l_b,min = 0.30

su2 = 0.4*esu2_nominal ((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 = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/l_d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

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 $f_{sv} = f_s = 311.2087$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.19518711$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09267877$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.17271953$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 25.3952$

$cc (5A.5, TBDY) = 0.0046976$

$c = \text{confinement factor} = 1.26976$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.27144518$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12888764$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.24019969$

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

--->

$su (4.8) = 0.32821401$

$Mu = MRc (4.15) = 4.2000E+008$

$u = su (4.1) = 1.3683079E-005$

Calculation of ratio lb/d

Inadequate Lap Length with $lb/d = 0.30$

Calculation of Mu_2 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 1.0987593E-005$

$Mu = 2.3956E+008$

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 : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01648022$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01648022$

we ((5.4c), TBDY) = $ase \cdot sh_{,min} \cdot fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.10530374$

where $f = af \cdot pf \cdot ff_e/f_{ce}$ 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 = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff_e = 703.4155$

$fy = 0.06888919$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.24098246$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff,e = 703.4155$

$R = 40.00$

Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.27151783$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 122525.00$ is 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).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00482813$

psh_x ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

c = confinement factor = 1.26976

$y1 = 0.0012967$

$sh1 = 0.0044814$

$ft1 = 373.4504$

$fy1 = 311.2087$

$su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su1 = 0.4*es_{u1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u1,nominal} = 0.08$,

For calculation of $es_{u1,nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 311.2087$

with $Es1 = Es = 200000.00$

$y2 = 0.0012967$

$sh2 = 0.0044814$

$ft2 = 373.4504$

$fy2 = 311.2087$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{s_u2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_u2,nominal} = 0.08$,

For calculation of $e_{s_u2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{s_y2} = f_{s_2}/1.2$, 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.

$$\text{with } f_{s_2} = f_s = 311.2087$$

$$\text{with } E_{s_2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{u_v} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$s_{u_v} = 0.4 * e_{s_{u_v},nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_{u_v},nominal} = 0.08$,

considering characteristic value $f_{s_{y_v}} = f_{s_v}/1.2$, from table 5.1, TBDY

For calculation of $e_{s_{u_v},nominal}$ and y_v, sh_v, ft_v, fy_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, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s_v} = f_s = 311.2087$$

$$\text{with } E_{s_v} = E_s = 200000.00$$

$$1 = A_{s_{l,ten}} / (b * d) * (f_{s_1} / f_c) = 0.03861616$$

$$2 = A_{s_{l,com}} / (b * d) * (f_{s_2} / f_c) = 0.08132796$$

$$v = A_{s_{l,mid}} / (b * d) * (f_{s_v} / f_c) = 0.07196647$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$c_c (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{s_{l,ten}} / (b * d) * (f_{s_1} / f_c) = 0.04534935$$

$$2 = A_{s_{l,com}} / (b * d) * (f_{s_2} / f_c) = 0.09550849$$

$$v = A_{s_{l,mid}} / (b * d) * (f_{s_v} / f_c) = 0.08451471$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16341093$$

$$M_u = M_{Rc} (4.14) = 2.3956E+008$$

$$u = s_u (4.1) = 1.0987593E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} * V_{Co10}$$

$$V_{Co10} = 424229.688$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$M/Vd = 4.00$
 $\mu_u = 46.90488$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:
 $V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 335103.216$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, 1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 424229.688$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} + f \cdot V_f$ '
 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)
 $M/Vd = 4.00$
 $\mu_u = 46.90486$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:
 $V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 335103.216$ is calculated for section flange, with:

d = 480.00
 Av = 157079.633
 fy = 444.4444
 s = 100.00
 Vs2 is multiplied by Col2 = 1.00
 s/d = 0.20833333
 Vf ((11-3)-(11.4), ACI 440) = 293495.545
 f = 0.95, for fully-wrapped sections
 wf/sf = 1 (FRP strips adjacent to one another).
 In (11.3) $\sin^2 + \cos^2$ is replaced with $(\cot^2 + \csc^2)\sin^2\alpha$ which is more a generalised expression,
 where 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: $\alpha_1 = b1 + 90^\circ = 90.00$
 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: 2

 Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
 At local axis: 2

Integration Section: (a)
 Section Type: rdcS

Constant Properties

 Knowledge Factor, $\gamma = 0.90$
 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 = 444.4444
 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
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with lb/ld = 0.30
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, t = 1.016
 Tensile Strength, ffu = 1055.00
 Tensile Modulus, Ef = 64828.00
 Elongation, efu = 0.01
 Number of directions, NoDir = 1
 Fiber orientations, bi: 0.00°

Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, M = -212984.263
Shear Force, V2 = -2808.718
Shear Force, V3 = 98.47243
Axial Force, F = -9398.91
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 $u,R = * u = 0.04187069$
 $u = y + p = 0.04652299$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00452299$ ((4.29), Biskinis Phd)
 $M_y = 2.6300E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2162.882
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9398.91$
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.6309447E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 248.9669$
 $d = 557.00$
 $y = 0.38448755$
 $A = 0.02987089$
 $B = 0.01925313$
with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9398.91$
 $b = 250.00$
 $" = 0.07719928$
 $y_{comp} = 8.1953602E-006$
with $f_c' (12.3, (ACI 440)) = 20.42407$
 $f_c = 20.00$
 $fl = 0.62098351$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $A_g = 237500.00$
 $g = pt + pc + pv = 0.02959978$
 $rc = 40.00$
 $A_e / A_c = 0.21783041$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38315868$
 $A = 0.02940683$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

- 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 $V_y E / C_o I_{OE} = 0.66001628$

$d = 557.00$

$s = 0.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = A_v \cdot L_{stir} / (A_g \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ 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.

$N_{UD} = 9398.91$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 11

column C1, Floor 1

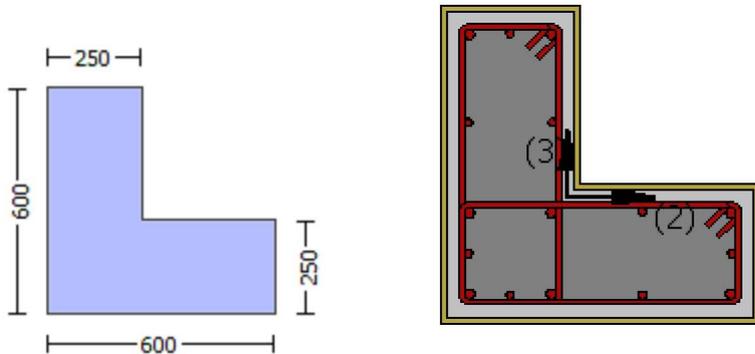
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$

#####

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

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -212984.263$
Shear Force, $V_a = 98.47243$
EDGE -B-
Bending Moment, $M_b = -81367.847$
Shear Force, $V_b = -98.47243$
BOTH EDGES
Axial Force, $F = -9398.91$
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: $As_{l,mid} = 1545.664$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = *V_n = 341627.22$
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI0} = 379585.80$
 $V_{CoI} = 379585.80$
 $knl = 1.00$
 $displacement_ductility_demand = 0.00691916$

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)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 212984.263$
 $V_u = 98.47243$
 $d = 0.8 * h = 480.00$
 $N_u = 9398.91$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 427256.601$
where:
 $V_{s1} = 301592.895$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.20833333$
 $V_{s2} = 125663.706$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, 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: $b_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, b_1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 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 $\theta = 3.1295261E-005$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00452299$ ((4.29), Biskinis Phd)

$M_y = 2.6300E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 2162.882

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9398.91$

$E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 3.6309447E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 248.9669$

$d = 557.00$

$y = 0.38448755$

$A = 0.02987089$

$B = 0.01925313$

with $p_t = 0.01254381$

$p_c = 0.00595605$

$p_v = 0.01109992$

$N = 9398.91$

$b = 250.00$

$\alpha = 0.07719928$

$y_{comp} = 8.1953602E-006$

with f_c^* (12.3, (ACI 440)) = 20.42407

$f_c = 20.00$

$f_l = 0.62098351$

$b = b_{max} = 600.00$

$h = h_{max} = 600.00$

$A_g = 237500.00$

$g = p_t + p_c + p_v = 0.02959978$

$r_c = 40.00$

$A_e / A_c = 0.21783041$

Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$

effective strain from (12.5) and (12.12), $e_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.38315868$

A = 0.02940683
B = 0.01898202
with Es = 200000.00

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 12

column C1, Floor 1

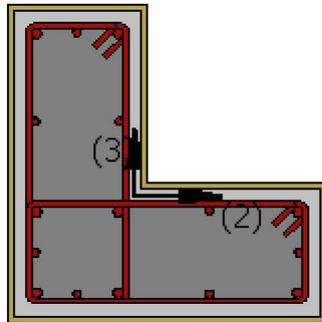
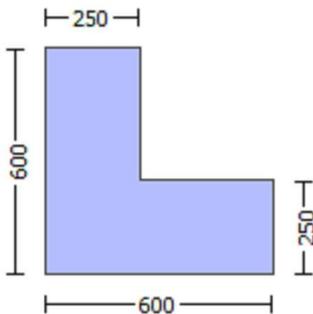
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

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: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

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 = 1.26976

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{o,min} = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00016213$

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 , $V_e/V_r = 0.66001628$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$

with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 4.2000E+008$
 $Mu_{1+} = 4.2000E+008$, 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
 $Mu_{1-} = 2.3956E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 4.2000E+008$
 $Mu_{2+} = 4.2000E+008$, 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
 $Mu_{2-} = 2.3956E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.3683079E-005$$

$$Mu = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00318999$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01648022$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00

fywe = 555.5556

fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.0046976

c = confinement factor = 1.26976

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19518711

2 = Asl,com/(b*d)*(fs2/fc) = 0.09267877

v = Asl,mid/(b*d)*(fsv/fc) = 0.17271953

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976
1 = $Asl_{ten}/(b*d)*(fs1/fc) = 0.27144518$
2 = $Asl_{com}/(b*d)*(fs2/fc) = 0.12888764$
v = $Asl_{mid}/(b*d)*(fsv/fc) = 0.24019969$

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) = 0.32821401
Mu = MRc (4.15) = 4.2000E+008
u = su (4.1) = 1.3683079E-005

Calculation of ratio lb/l_d

Inadequate Lap Length with lb/l_d = 0.30

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.0987593E-005
Mu = 2.3956E+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: $cu^* = shear_factor * Max(cu, cc) = 0.01648022$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $cu = 0.01648022$
 $we ((5.4c), TBDY) = ase * sh_{,min} * fy_{we}/f_{ce} + Min(f_x, f_y) = 0.10530374$
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 $af = 1 - (Unconfined\ area)/(total\ area)$

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 $af = 1 - (Unconfined\ area)/(total\ area)$

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

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 122525.00$ is 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).

$$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00482813$$

$$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

using (30) in Bisquinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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.

$$\text{with } fs_1 = fs = 311.2087$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$su_2 = 0.00512$$

using (30) in Bisquinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_{b,min} = 0.30$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2 / 1.2$, from table 5.1, TBDY.

y_2 , sh_2 , ft_2 , fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 311.2087$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^2/3), from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616

2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796

v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = Asl,ten/(b*d)*(fs1/fc) = 0.04534935

2 = Asl,com/(b*d)*(fs2/fc) = 0.09550849

v = Asl,mid/(b*d)*(fsv/fc) = 0.08451471

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vs,y2 - LHS eq.(4.5) is satisfied

su (4.9) = 0.16341093

Mu = MRc (4.14) = 2.3956E+008

u = su (4.1) = 1.0987593E-005

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.3683079E-005

Mu = 4.2000E+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* = shear_factor * Max(cu, cc) = 0.01648022

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01648022

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.10530374

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 = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $pf = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.24098246$

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), $pf = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL*t*\text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}), 0) = 0.27151783$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ 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.

$A_{conf,min} = 122525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su_1 = 0.4*esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25*(l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4504$
 $fy_2 = 311.2087$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 0.30$
 $su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2_nominal} = 0.08$,
 For calculation of $esu_{2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 311.2087$
 with $Es_2 = Es = 200000.00$

$y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and 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 $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$

$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.19518711$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.09267877$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.17271953$

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.27144518$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.12888764$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.24019969$

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

--->
 $su (4.8) = 0.32821401$
 $Mu = MRc (4.15) = 4.2000E+008$
 $u = su (4.1) = 1.3683079E-005$

 Calculation of ratio lb/ld

 Inadequate Lap Length with $lb/ld = 0.30$

 Calculation of Mu_2 -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0987593E-005$$

$$Mu = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01648022$$

$$\phi_{we} \text{ ((5.4c), TBDY) } = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.10530374$$

where $\phi = a_f * \phi_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$\phi_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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)

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$A_{\text{conf,max}} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 122525.00$ 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).

$$\phi_{sh, \min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00482813$$

$$\phi_{sh,x} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 237500.00$$

$$\phi_{sh,y} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 237500.00$$

$s = 100.00$
 $fy_{we} = 555.5556$
 $f_{ce} = 20.00$
 From ((5.A.5), TBDY), TBDY: $cc = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $y_1 = 0.0012967$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4504$
 $fy_1 = 311.2087$
 $su_1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/d = 0.30$
 $su_1 = 0.4 * esu_1 \text{nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu_1 \text{nominal} = 0.08$,
 For calculation of $esu_1 \text{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 311.2087$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.0012967$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4504$
 $fy_2 = 311.2087$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/lb, \text{min} = 0.30$
 $su_2 = 0.4 * esu_2 \text{nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu_2 \text{nominal} = 0.08$,
 For calculation of $esu_2 \text{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 311.2087$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/d = 0.30$
 $suv = 0.4 * esuv \text{nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv \text{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv \text{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2087$
 with $Es_v = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.03861616$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.08132796$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.07196647$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, \text{TBDY}) = 25.3952$
 $cc (5A.5, \text{TBDY}) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.04534935$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.09550849$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08451471$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.16341093$$

$$M_u = M_{Rc}(4.14) = 2.3956E+008$$

$$u = s_u(4.1) = 1.0987593E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$V_{r1} = V_{Col}((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$

$$V_{Col0} = 424229.688$$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+ f} \cdot V_f$ '
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)

$$M/Vd = 4.00$$

$$M_u = 46.90894$$

$$V_u = 0.00016213$$

$$d = 0.8 \cdot h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 474729.557$$

where:

$V_{s1} = 335103.216$ is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

V_{s1} is multiplied by $Col1 = 1.00$

$$s/d = 0.20833333$$

$V_{s2} = 139626.34$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

V_{s2} is multiplied by $Col2 = 1.00$

$$s/d = 0.50$$

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 $V_f(\alpha, a_1)$, 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: $\alpha = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

f_{fe} ((11-5), ACI 440) = 259.312

$$E_f = 64828.00$$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 424229.688$
 $knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 46.90897$
 $Vu = 0.00016213$
 $d = 0.8 * h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$

where:

$V_{s1} = 335103.216$ is calculated for section web, with:

$d = 480.00$
 $Av = 157079.633$
 $fy = 444.4444$
 $s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.20833333$

$V_{s2} = 139626.34$ is calculated for section flange, with:

$d = 200.00$
 $Av = 157079.633$
 $fy = 444.4444$
 $s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.50$

$V_f ((11-3)-(11.4), ACI 440) = 293495.545$

$f = 0.95$, 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, $tf1 = NL * t / \text{NoDir} = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 557.00

$ffe ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$fe = 0.004$, from (11.6a), ACI 440

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rdcs

Constant Properties

Knowledge Factor, $\phi = 0.90$
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, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

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 = 1.26976
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 0.00016213$
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 , $V_e/V_r = 0.66001628$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$
with
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 4.2000E+008$
 $M_{u1+} = 4.2000E+008$, 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
 $M_{u1-} = 2.3956E+008$, 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.2000E+008$$

$M_{u2+} = 4.2000E+008$, 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

$M_{u2-} = 2.3956E+008$, 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:

$$\phi_u = 1.3683079E-005$$

$$M_u = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$\alpha_{co} \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01648022$$

$$\phi_{we} \text{ ((5.4c), TBDY)} = \alpha_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.10530374$$

where $\phi_f = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$\phi_{fy} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00482813$$

$$psh,x ((5.4d), \text{TBDY}) = Lstir * Astir / (Asec * s) = 0.00482813$$

$$Lstir (\text{Length of stirrups along Y}) = 1460.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 237500.00$$

$$psh,y ((5.4d), \text{TBDY}) = Lstir * Astir / (Asec * s) = 0.00482813$$

$$Lstir (\text{Length of stirrups along X}) = 1460.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 237500.00$$

$$s = 100.00$$

$$fywe = 555.5556$$

$$fce = 20.00$$

$$\text{From } ((5.A5), \text{TBDY}), \text{TBDY: } cc = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$y1 = 0.0012967$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4504$$

$$fy1 = 311.2087$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$$

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.

$$\text{with } fs1 = fs = 311.2087$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0012967$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4504$$

$$fy2 = 311.2087$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$$

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.

$$\text{with } fs2 = fs = 311.2087$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0012967$$

$$shv = 0.0044814$$

$$ftv = 373.4504$$

$$fyv = 311.2087$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$$

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.

$$\text{with } fsv = fs = 311.2087$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.19518711$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09267877$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.17271953$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$c_c (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.27144518$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12888764$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.24019969$$

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

--->

$$s_u (4.8) = 0.32821401$$

$$M_u = M_{Rc} (4.15) = 4.2000E+008$$

$$u = s_u (4.1) = 1.3683079E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0987593E-005$$

$$M_u = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01648022$$

$$w_e ((5.4c), TBDY) = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 600.00$$

hmax = 600.00
From EC8 A.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase = \text{Max}((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}} * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$
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.
 $A_{\text{conf,min}} = 122525.00$ 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$
 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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

s = 100.00
 $f_{ywe} = 555.5556$
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.0046976
c = confinement factor = 1.26976

$y1 = 0.0012967$
 $sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: $esu1_{\text{nominal}} = 0.08$,

For calculation of $esu1_{\text{nominal}}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 311.2087$

with $Es1 = Es = 200000.00$

$y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$su2 = 0.4 * esu2_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: $esu2_{\text{nominal}} = 0.08$,

For calculation of $esu2_{\text{nominal}}$ and $y2, sh2, ft2, fy2$, it is considered

characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $f_{s2} = f_s = 311.2087$
with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $f_{y_v} = 311.2087$
 $s_{u_v} = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30$

$s_{u_v} = 0.4 \cdot e_{s_{u_v,nominal}} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{s_{u_v,nominal}} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{s_{u_v,nominal}}$ and y_v, sh_v, ft_v, f_{y_v} , it is considered
characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $f_{sv} = f_s = 311.2087$

with $E_{sv} = E_s = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03861616$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08132796$

v = $As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07196647$

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

f_{cc} (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04534935$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09550849$

v = $As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08451471$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < v_{s,y2} - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16341093

Mu = MRc (4.14) = 2.3956E+008

u = su (4.1) = 1.0987593E-005

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Mu2+

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

u = 1.3683079E-005

Mu = 4.2000E+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 ϕ_u : $\phi_u^* = \text{shear_factor} \cdot \text{Max}(\phi_u, \phi_c) = 0.01648022$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01648022$

we ((5.4c), TBDY) = $a_{se} * sh_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$

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, $t_f = NL * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 122525.00$ is 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.30$$

$$s_u1 = 0.4 * e_{su1,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su1,nominal} = 0.08$,

For calculation of $e_{su1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $f_{sy1} = f_{s1}/1.2$, 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.

$$\text{with } f_{s1} = f_s = 311.2087$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$s_u2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,

For calculation of $e_{su2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_{s2}/1.2$, 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.

$$\text{with } f_{s2} = f_s = 311.2087$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{uv} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, 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.

$$\text{with } f_{sv} = f_s = 311.2087$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19518711$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09267877$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.17271953$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$c_c (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.27144518$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.12888764$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.24019969$$

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

--->

$$s_u (4.8) = 0.32821401$$

$$\mu_u = M_{Rc} (4.15) = 4.2000E+008$$

$$u = s_u (4.1) = 1.3683079E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.0987593E-005$$

$$\mu_2 = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_0 \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear_factor} * \text{Max}(\mu_2, c_0) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_2 = 0.01648022$$

$$\mu_2 \text{ (5.4c), TBDY} = a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.10530374$$

where $\mu_x = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$\mu_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.27151783$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 122525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

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) = 0.00482813
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976
c = confinement factor = 1.26976

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616

2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796

v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04534935$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09550849$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08451471$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16341093$
 $Mu = MRc (4.14) = 2.3956E+008$
 $u = su (4.1) = 1.0987593E-005$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$
 $V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = knl * V_{Co10}$
 $V_{Co10} = 424229.688$
 $knl = 1$ (zero step-static loading)

 NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
 where Vf is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 46.90488$
 $Vu = 0.00016213$
 $d = 0.8*h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:
 $V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 335103.216$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, 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 $V_f(\theta, \alpha)$, 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, $V_{r2} = 424229.688$
 $V_{r2} = V_{CoI} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{CoI0}$
 $V_{CoI0} = 424229.688$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+ f \cdot V_f}$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 46.90486$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
where:

$V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$

$V_{s2} = 335103.216$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$

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: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$

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

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -8.5372E+006$

Shear Force, $V_2 = -2808.718$

Shear Force, $V_3 = 98.47243$

Axial Force, $F = -9398.91$

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 $u_{,R} = \gamma \cdot u = 0.04352062$

$u = \gamma \cdot u_p = 0.04835624$

- Calculation of γ -

$\gamma = (M_y \cdot L_s / 3) / E_{eff} = 0.00635624 ((4.29), Biskinis Phd))$

My = 2.6300E+008
Ls = M/V (with Ls > 0.1*L and Ls < 2*L) = 3039.539
From table 10.5, ASCE 41_17: Eleff = factor*Ec*Ig = 4.1921E+013
factor = 0.30
Ag = 237500.00
fc' = 20.00
N = 9398.91
Ec*Ig = 1.3974E+014

Calculation of Yielding Moment My

Calculation of ρ_y and My according to Annex 7 -

y = Min(ρ_{y_ten} , ρ_{y_com})
 ρ_{y_ten} = 3.6309447E-006
with ((10.1), ASCE 41-17) $\rho_y = \text{Min}(\rho_y, 1.25*\rho_y*(l_b/d)^{2/3}) = 248.9669$
d = 557.00
y = 0.38448755
A = 0.02987089
B = 0.01925313
with $\rho_{pt} = 0.01254381$
pc = 0.00595605
pv = 0.01109992
N = 9398.91
b = 250.00
" = 0.07719928
 ρ_{y_comp} = 8.1953602E-006
with ρ_{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 = $\rho_{pt} + \rho_{pc} + \rho_{pv} = 0.02959978$
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), $\epsilon_{fe} = 0.004$
 $\rho_u = 0.01$
Ef = 64828.00
Ec = 21019.039
y = 0.38315868
A = 0.02940683
B = 0.01898202
with Es = 200000.00

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

- Calculation of ρ_p -

From table 10-8: $\rho_p = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$
shear control ratio $V_y E / V_{CoI} O E = 0.66001628$
d = 557.00
s = 0.00
 $t = A_v / (b_w * s) + 2 * t_f / b_w * (\rho_{fe} / \rho_{fs}) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (\rho_{fe} / \rho_{fs}) = 0.00$
Av = 78.53982, is the area of every stirrup
Lstir = 1460.00, is the total Length of all stirrups parallel to loading (shear) direction
The term $2 * t_f / b_w * (\rho_{fe} / \rho_{fs})$ 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 = 9398.91

Ag = 237500.00

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$pl = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.02959978$

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: (a)

Calculation No. 13

column C1, Floor 1

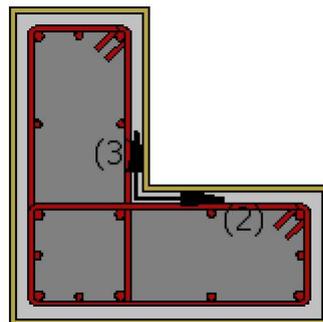
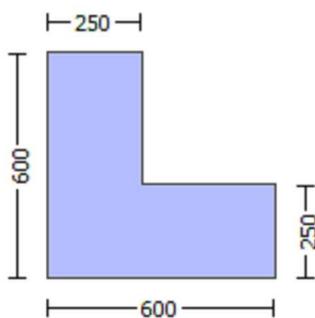
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

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: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$
 #####
 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
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

 Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -8.5372E+006$
 Shear Force, $V_a = -2808.718$
 EDGE -B-
 Bending Moment, $M_b = 108192.18$
 Shear Force, $V_b = 2808.718$
 BOTH EDGES
 Axial Force, $F = -9398.91$
 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 $V_R = \phi V_n = 396275.185$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 440305.761$
 $V_{CoI} = 440305.761$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.05017969$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ $f \phi V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 108192.18$
 $V_u = 2808.718$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9398.91$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 427256.601$
 where:
 $V_{s1} = 125663.706$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 301592.895$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 V_f ((11-3)-(11.4), ACI 440) = 293495.545
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a_i)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, 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 B -
 for rotation axis 3 and integ. section (b)

 From analysis, chord rotation $\theta = 3.1480520E-005$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00062736$ ((4.29), Biskinis Phd)
 $M_y = 2.6300E+008$
 $L_s = M/V$ (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
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9398.91$
 $E_c \cdot I_g = 1.3974E+014$

 Calculation of Yielding Moment M_y

 Calculation of δ / y and M_y according to Annex 7 -

 $y = \text{Min}(\delta_{ten}, \delta_{com})$

y_ten = 3.6309447E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^ 2/3) = 248.9669
d = 557.00
y = 0.38448755
A = 0.02987089
B = 0.01925313
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9398.91
b = 250.00
" = 0.07719928
y_comp = 8.1953602E-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 = 0.38315868
A = 0.02940683
B = 0.01898202
with Es = 200000.00

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

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

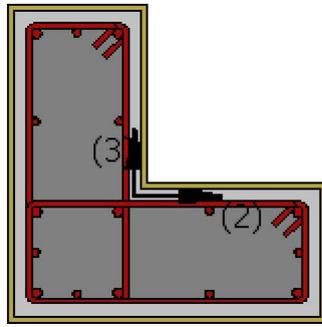
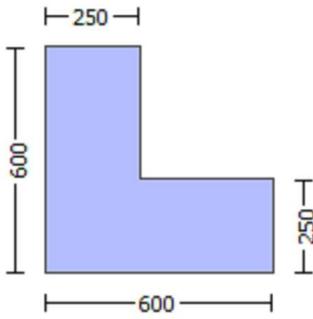
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$
 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, $f_s = f_{sm} = 444.4444$
 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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

 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 = 1.26976
 Element Length, $L = 3000.00$

Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, $V_a = 0.00016213$
 EDGE -B-
 Shear Force, $V_b = -0.00016213$

BOTH EDGES

Axial Force, $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{,ten} = 1746.726$

-Compression: $As_{,com} = 829.3805$

-Middle: $As_{,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.66001628$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.2000E+008$

$Mu_{1+} = 4.2000E+008$, 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

$Mu_{1-} = 2.3956E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.2000E+008$

$Mu_{2+} = 4.2000E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.3956E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.3683079E-005$

$M_u = 4.2000E+008$

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_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01648022$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01648022$

where ϕ_u ((5.4c), TBDY) = $a_s e^* \phi_{u, \text{min}} * f_{y, \text{we}} / f_{c, \text{e}} + \text{Min}(\phi_x, \phi_y) = 0.10530374$

where $\phi = a_f * \phi_f * f_{f, \text{e}} / f_{c, \text{e}}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.24098246$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 57233.333$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f, \text{e}} = 703.4155$

$\phi_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.24098246$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 0.00$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

From EC8 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, $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 122525.00$ is 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).
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00482813$

psh,x ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

s = 100.00

$f_{ywe} = 555.5556$

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976

c = confinement factor = 1.26976

$y1 = 0.0012967$

$sh1 = 0.0044814$

$ft1 = 373.4504$

$fy1 = 311.2087$

$su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 311.2087$

with $Es1 = Es = 200000.00$

$y2 = 0.0012967$

$sh2 = 0.0044814$

$ft2 = 373.4504$

$fy2 = 311.2087$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$su2 = 0.4 * esu2_{nominal}$ ((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 $fs2 = fs = 311.2087$

with $Es2 = Es = 200000.00$

$yv = 0.0012967$

$shv = 0.0044814$

$ftv = 373.4504$

$fyv = 311.2087$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lou, \min = lb/ld = 0.30$

$suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$

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 $fsv = fs = 311.2087$

with $Es = Es = 200000.00$

1 = $Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.19518711$

2 = $Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.09267877$

$v = Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.17271953$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 25.3952$

$cc (5A.5, TBDY) = 0.0046976$

$c = \text{confinement factor} = 1.26976$

1 = $Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.27144518$

2 = $Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.12888764$

$v = Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.24019969$

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

$su (4.8) = 0.32821401$

$Mu = MRc (4.15) = 4.2000E+008$

$u = su (4.1) = 1.3683079E-005$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of $Mu1$ -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 1.0987593E-005$

$Mu = 2.3956E+008$

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 c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01648022$

w_e ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$

where $f = af * pf * ff_e / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.24098246$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff_e = 703.4155$

 $f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.24098246$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff_e = 703.4155$

 $R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 122525.00$ is 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 100.00$

$fy_{we} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

$c = \text{confinement factor} = 1.26976$

$y1 = 0.0012967$

$sh1 = 0.0044814$

$ft1 = 373.4504$

$fy1 = 311.2087$

$su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616

2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796

v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = Asl,ten/(b*d)*(fs1/fc) = 0.04534935

2 = Asl,com/(b*d)*(fs2/fc) = 0.09550849

v = Asl,mid/(b*d)*(fsv/fc) = 0.08451471

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16341093

Mu = MRc (4.14) = 2.3956E+008

u = su (4.1) = 1.0987593E-005

Calculation of ratio lb/d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.3683079E-005$$

$$\mu = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01648022$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 122525.00$ is 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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00482813
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976
c = confinement factor = 1.26976

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19518711
2 = Asl,com/(b*d)*(fs2/fc) = 0.09267877
v = Asl,mid/(b*d)*(fsv/fc) = 0.17271953

and confined core properties:

b = 190.00

$d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.27144518$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12888764$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.24019969$
 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
 --->

$su (4.8) = 0.32821401$
 $Mu = MRc (4.15) = 4.2000E+008$
 $u = su (4.1) = 1.3683079E-005$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Mu_2 -

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.0987593E-005$
 $Mu = 2.3956E+008$

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 : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01648022$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01648022$
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$
 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, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 122525.00$ is 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).

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00482813$

$psh_{,x}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00482813$

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) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{,min} = lb/ld = 0.30$

$su_1 = 0.4 \cdot esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$

$sh_2 = 0.0044814$

$ft_2 = 373.4504$

$fy_2 = 311.2087$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{,min} = lb/lb_{,min} = 0.30$

$su_2 = 0.4 \cdot esu_{2,nominal}$ ((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_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 311.2087$

with $Es_2 = Es = 200000.00$

$y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/d = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fs_v = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_v = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.03861616$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.08132796$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.07196647$

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.04534935$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.09550849$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08451471$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

$su (4.9) = 0.16341093$
 $Mu = MRc (4.14) = 2.3956E+008$
 $u = su (4.1) = 1.0987593E-005$

Calculation of ratio lb/d

Inadequate Lap Length with $lb/d = 0.30$

Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = knl * V_{Co10}$

$V_{Co10} = 424229.688$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
 where Vf is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 46.90894$
 $Vu = 0.00016213$
 $d = 0.8 * h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:

Vs1 = 335103.216 is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs1 is multiplied by Col1 = 1.00

$$s/d = 0.20833333$$

Vs2 = 139626.34 is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.50$$

Vf ((11-3)-(11.4), ACI 440) = 293495.545

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where 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: $\theta = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

f_{fe} ((11-5), ACI 440) = 259.312

$$E_f = 64828.00$$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$

$$V_{Col0} = 424229.688$$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$M_u = 46.90897$$

$$V_u = 0.00016213$$

$$d = 0.8 \cdot h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$

where:

Vs1 = 335103.216 is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs1 is multiplied by Col1 = 1.00

$$s/d = 0.20833333$$

Vs2 = 139626.34 is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.50$$

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 $V_f(\theta, \alpha)$, 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (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: rdlcs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

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 = 1.26976

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou, min} = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $\text{NoDir} = 1$

Fiber orientations, $\theta_i: 0.00^\circ$

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: $As_t = 0.00$

-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: $As_{mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.66001628$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 4.2000E+008$

$M_{u1+} = 4.2000E+008$, 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

$M_{u1-} = 2.3956E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.2000E+008$

$M_{u2+} = 4.2000E+008$, 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

$M_{u2-} = 2.3956E+008$, 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:

$\phi_u = 1.3683079E-005$

$M_u = 4.2000E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01648022$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_{cu} = 0.01648022$

ω_e ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.24098246$

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, $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su_1 = 0.4 * esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$

$sh_2 = 0.0044814$

$ft_2 = 373.4504$

$fy_2 = 311.2087$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{su2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2_nominal} = 0.08$,

For calculation of $e_{su2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 311.2087$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{uv} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, 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.

$$\text{with } f_{sv} = f_s = 311.2087$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19518711$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.09267877$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.17271953$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$cc (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.27144518$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.12888764$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.24019969$$

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

---->

$$s_u (4.8) = 0.32821401$$

$$M_u = M_{Rc} (4.15) = 4.2000E+008$$

$$u = s_u (4.1) = 1.3683079E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0987593E-005$$

$$M_u = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \alpha = 0.01648022$$

$$\text{where } \alpha_c \text{ ((5.4c), TBDY) = } \alpha_{se} * \text{sh}_{,\min} * f_{ywe} / f_{ce} + \text{Min}(\alpha_x, \alpha_y) = 0.10530374$$

where $\alpha = \alpha^* \text{pf} * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\alpha_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \text{pf} = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$\alpha_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \text{pf} = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$\text{psh}_{,\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00482813$$

$$\text{psh}_x \text{ ((5.4d), TBDY) = } L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) = } 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area) = } 78.53982$$

$$A_{\text{sec}} \text{ (section area) = } 237500.00$$

$$\text{psh}_y \text{ ((5.4d), TBDY) = } L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) = } 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area) = } 78.53982$$

$$A_{\text{sec}} \text{ (section area) = } 237500.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \alpha_c = 0.0046976$$

$c = \text{confinement factor} = 1.26976$
 $y1 = 0.0012967$
 $sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.30$
 $su1 = 0.4*esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fs1 = fs = 311.2087$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/lb,min = 0.30$
 $su2 = 0.4*esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fs2 = fs = 311.2087$
 with $Es2 = Es = 200000.00$
 $yv = 0.0012967$
 $shv = 0.0044814$
 $ftv = 373.4504$
 $fyv = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.30$
 $suv = 0.4*esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 25.3952$
 $cc (5A.5, \text{TBDY}) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.04534935$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.09550849$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.08451471$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.16341093$$

$$M_u = M_{Rc}(4.14) = 2.3956E+008$$

$$u = s_u(4.1) = 1.0987593E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u2+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.3683079E-005$$

$$M_u = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01648022$$

$$\phi_{cc} \text{ ((5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.10530374$$

where $\phi_f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$\phi_{fy} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.27151783$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

Aconf,min = 122525.00 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) = 0.00482813

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00482813
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) = 0.00482813
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00

fywe = 555.5556

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976

c = confinement factor = 1.26976

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/l_d = 0.30

su1 = 0.4*esu1_nominal ((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 = fs/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/l_d)^2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/l_b,min = 0.30

su2 = 0.4*esu2_nominal ((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 = fs/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/l_d)^2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/l_d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

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 $f_{sv} = f_s = 311.2087$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.19518711$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09267877$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.17271953$

and confined core properties:

$b = 190.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 25.3952$

$cc (5A.5, TBDY) = 0.0046976$

$c = \text{confinement factor} = 1.26976$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.27144518$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12888764$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.24019969$

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

--->

$su (4.8) = 0.32821401$

$Mu = MRc (4.15) = 4.2000E+008$

$u = su (4.1) = 1.3683079E-005$

Calculation of ratio lb/d

Inadequate Lap Length with $lb/d = 0.30$

Calculation of Mu_2 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 1.0987593E-005$

$Mu = 2.3956E+008$

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 : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01648022$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01648022$

$w_e ((5.4c), TBDY) = a_{se} \cdot sh_{,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$

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), $f_{fe} = 703.4155$

$f_y = 0.06888919$

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, $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.27151783$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ 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.

$A_{conf,min} = 122525.00$ is 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).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00482813$

psh_x ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

c = confinement factor = 1.26976

$y1 = 0.0012967$

$sh1 = 0.0044814$

$ft1 = 373.4504$

$fy1 = 311.2087$

$su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su1 = 0.4*es_{u1_nominal}$ ((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 $\text{Min}(1, 1.25*(l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y2 = 0.0012967$

$sh2 = 0.0044814$

$ft2 = 373.4504$

$fy2 = 311.2087$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{s_u2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_u2,nominal} = 0.08$,

For calculation of $e_{s_u2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{s_y2} = f_{s_2}/1.2$, 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.

$$\text{with } f_{s_2} = f_s = 311.2087$$

$$\text{with } E_{s_2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{u_v} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$s_{u_v} = 0.4 * e_{s_{u_v},nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_{u_v},nominal} = 0.08$,

considering characteristic value $f_{s_{y_v}} = f_{s_v}/1.2$, from table 5.1, TBDY

For calculation of $e_{s_{u_v},nominal}$ and y_v, sh_v, ft_v, fy_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, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s_v} = f_s = 311.2087$$

$$\text{with } E_{s_v} = E_s = 200000.00$$

$$1 = A_{s_l,ten}/(b*d)*(f_{s_1}/f_c) = 0.03861616$$

$$2 = A_{s_l,com}/(b*d)*(f_{s_2}/f_c) = 0.08132796$$

$$v = A_{s_l,mid}/(b*d)*(f_{s_v}/f_c) = 0.07196647$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$c_c (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{s_l,ten}/(b*d)*(f_{s_1}/f_c) = 0.04534935$$

$$2 = A_{s_l,com}/(b*d)*(f_{s_2}/f_c) = 0.09550849$$

$$v = A_{s_l,mid}/(b*d)*(f_{s_v}/f_c) = 0.08451471$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16341093$$

$$M_u = M_{Rc} (4.14) = 2.3956E+008$$

$$u = s_u (4.1) = 1.0987593E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} * V_{Co10}$$

$$V_{Co10} = 424229.688$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} f^* V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$M/Vd = 4.00$
 $\mu_u = 46.90488$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:
 $V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 335103.216$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, 1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 424229.688$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\mu_u = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 46.90486$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:
 $V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 335103.216$ is calculated for section flange, with:

$d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
Vs2 is multiplied by Col2 = 1.00
 $s/d = 0.20833333$
 $V_f((11-3)-(11.4), \text{ACI 440}) = 293495.545$
 $f = 0.95$, 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 a is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
At local axis: 2

Integration Section: (b)
Section Type: rdcS

Constant Properties

Knowledge Factor, $\gamma = 0.90$
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, $f_s = f_{sm} = 444.4444$
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
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_b/l_d = 0.30$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $\text{NoDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$

Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, M = -81367.847
Shear Force, V2 = 2808.718
Shear Force, V3 = -98.47243
Axial Force, F = -9398.91
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 $u,R = \phi u = 0.03935515$
 $u = y + p = 0.04372795$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00172795$ ((4.29), Biskinis Phd)
 $M_y = 2.6300E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 826.3008
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9398.91$
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.6309447E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 248.9669$
 $d = 557.00$
 $y = 0.38448755$
 $A = 0.02987089$
 $B = 0.01925313$
with $p_t = 0.01254381$
 $p_c = 0.00595605$
 $p_v = 0.01109992$
 $N = 9398.91$
 $b = 250.00$
 $" = 0.07719928$
 $y_{comp} = 8.1953602E-006$
with $f_c' (12.3, (ACI 440)) = 20.42407$
 $f_c = 20.00$
 $f_l = 0.62098351$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $A_g = 237500.00$
 $g = p_t + p_c + p_v = 0.02959978$
 $rc = 40.00$
 $A_e / A_c = 0.21783041$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38315868$
 $A = 0.02940683$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

- 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 $V_y E / C_o I_{OE} = 0.66001628$

$d = 557.00$

$s = 0.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = A_v \cdot L_{stir} / (A_g \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ 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.

$N_{UD} = 9398.91$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 15

column C1, Floor 1

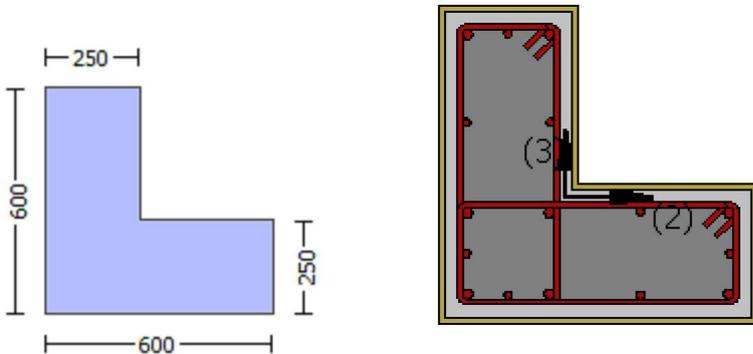
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$

#####

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

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -212984.263$
Shear Force, $V_a = 98.47243$
EDGE -B-
Bending Moment, $M_b = -81367.847$
Shear Force, $V_b = -98.47243$
BOTH EDGES
Axial Force, $F = -9398.91$
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: $As_{l,mid} = 1545.664$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = *V_n = 396275.185$
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI0} = 440305.761$
 $V_{CoI} = 440305.761$
 $knl = 1.00$
 $displacement_ductility_demand = 1.2421916E-005$

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)
 $M/Vd = 2.00$
 $M_u = 81367.847$
 $V_u = 98.47243$
 $d = 0.8 * h = 480.00$
 $N_u = 9398.91$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 427256.601$
where:
 $V_{s1} = 301592.895$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.20833333$
 $V_{s2} = 125663.706$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 318865.838$

$b_w = 250.00$

displacement ductility demand is calculated as δ / y

- Calculation of δ / y for END B -

for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 2.1464433E-008$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00172795$ ((4.29), Biskinis Phd)

$M_y = 2.6300E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 826.3008

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9398.91$

$E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 3.6309447E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 248.9669$

$d = 557.00$

$y = 0.38448755$

$A = 0.02987089$

$B = 0.01925313$

with $p_t = 0.01254381$

$p_c = 0.00595605$

$p_v = 0.01109992$

$N = 9398.91$

$b = 250.00$

$\alpha = 0.07719928$

$y_{comp} = 8.1953602E-006$

with f_c^* (12.3, (ACI 440)) = 20.42407

$f_c = 20.00$

$f_l = 0.62098351$

$b = b_{max} = 600.00$

$h = h_{max} = 600.00$

$A_g = 237500.00$

$g = p_t + p_c + p_v = 0.02959978$

$r_c = 40.00$

$A_e / A_c = 0.21783041$

Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b1) = 1.016$

effective strain from (12.5) and (12.12), $e_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.38315868$

A = 0.02940683
B = 0.01898202
with Es = 200000.00

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

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

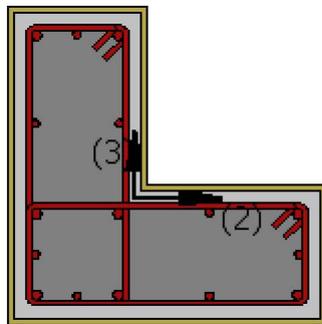
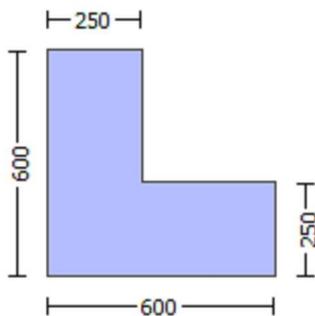
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

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 = 1.26976

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00016213$

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 , $V_e/V_r = 0.66001628$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$

with

$M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 4.2000E+008$

$Mu_{1+} = 4.2000E+008$, 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

$Mu_{1-} = 2.3956E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 4.2000E+008$

$Mu_{2+} = 4.2000E+008$, 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

$Mu_{2-} = 2.3956E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.3683079E-005$$

$$Mu = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01648022$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e^* s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00

fywe = 555.5556

fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.0046976

c = confinement factor = 1.26976

y1 = 0.0012967

sh1 = 0.0044814

ft1 = 373.4504

fy1 = 311.2087

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967

sh2 = 0.0044814

ft2 = 373.4504

fy2 = 311.2087

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967

shv = 0.0044814

ftv = 373.4504

fyv = 311.2087

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19518711

2 = Asl,com/(b*d)*(fs2/fc) = 0.09267877

v = Asl,mid/(b*d)*(fsv/fc) = 0.17271953

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976
1 = $Asl_{ten}/(b*d)*(fs1/fc) = 0.27144518$
2 = $Asl_{com}/(b*d)*(fs2/fc) = 0.12888764$
v = $Asl_{mid}/(b*d)*(fsv/fc) = 0.24019969$

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) = 0.32821401
Mu = MRc (4.15) = 4.2000E+008
u = su (4.1) = 1.3683079E-005

Calculation of ratio lb/l_d

Inadequate Lap Length with lb/l_d = 0.30

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.0987593E-005
Mu = 2.3956E+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: $cu^* = shear_factor * Max(cu, cc) = 0.01648022$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $cu = 0.01648022$
 $we ((5.4c), TBDY) = ase * sh_{,min} * fy_{we}/f_{ce} + Min(f_x, f_y) = 0.10530374$
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 $af = 1 - (Unconfined\ area)/(total\ area)$
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 $af = 1 - (Unconfined\ area)/(total\ area)$
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

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 122525.00$ is 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).

$$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00482813$$

$$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$f_{ywe} = 555.5556$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$y_1 = 0.0012967$$

$$sh_1 = 0.0044814$$

$$ft_1 = 373.4504$$

$$fy_1 = 311.2087$$

$$su_1 = 0.00512$$

using (30) in Bisquinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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.

$$\text{with } fs_1 = fs = 311.2087$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$su_2 = 0.00512$$

using (30) in Bisquinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_{b,min} = 0.30$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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.

$$\text{with } fs_2 = fs = 311.2087$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616

2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796

v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647

and confined core properties:

b = 540.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 25.3952

cc (5A.5, TBDY) = 0.0046976

c = confinement factor = 1.26976

1 = Asl,ten/(b*d)*(fs1/fc) = 0.04534935

2 = Asl,com/(b*d)*(fs2/fc) = 0.09550849

v = Asl,mid/(b*d)*(fsv/fc) = 0.08451471

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16341093

Mu = MRc (4.14) = 2.3956E+008

u = su (4.1) = 1.0987593E-005

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.3683079E-005

Mu = 4.2000E+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* = shear_factor * Max(cu, cc) = 0.01648022

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01648022

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.10530374

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 = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $pf = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.24098246$

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), $pf = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL*t*\text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}), 0) = 0.27151783$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ 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.

$A_{conf,min} = 122525.00$ is 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su_1 = 0.4*esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25*(l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 311.2087$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0012967$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4504$
 $fy_2 = 311.2087$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 0.30$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 311.2087$
 with $Es_2 = Es = 200000.00$

$y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and 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 $fsv = fs = 311.2087$
 with $Esv = Es = 200000.00$

$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.19518711$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.09267877$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.17271953$

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.27144518$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.12888764$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.24019969$

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

---->
 $su (4.8) = 0.32821401$
 $Mu = MRc (4.15) = 4.2000E+008$
 $u = su (4.1) = 1.3683079E-005$

 Calculation of ratio lb/ld

 Inadequate Lap Length with $lb/ld = 0.30$

 Calculation of Mu_2 -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0987593E-005$$

$$Mu = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01648022$$

$$\phi_{we} \text{ ((5.4c), TBDY) } = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.10530374$$

where $\phi = a_f * \phi_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$\phi_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$\phi_{sh, \min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00482813$$

$$\phi_{sh,x} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 237500.00$$

$$\phi_{sh,y} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 237500.00$$

$s = 100.00$
 $fy_{we} = 555.5556$
 $f_{ce} = 20.00$
 From ((5.A.5), TBDY), TBDY: $cc = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $y_1 = 0.0012967$
 $sh_1 = 0.0044814$
 $ft_1 = 373.4504$
 $fy_1 = 311.2087$
 $su_1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/d = 0.30$
 $su_1 = 0.4 * esu_1 \text{nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu_1 \text{nominal} = 0.08$,
 For calculation of $esu_1 \text{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 311.2087$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.0012967$
 $sh_2 = 0.0044814$
 $ft_2 = 373.4504$
 $fy_2 = 311.2087$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/lb, \text{min} = 0.30$
 $su_2 = 0.4 * esu_2 \text{nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu_2 \text{nominal} = 0.08$,
 For calculation of $esu_2 \text{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 311.2087$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $fy_v = 311.2087$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/d = 0.30$
 $suv = 0.4 * esuv \text{nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv \text{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv \text{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 311.2087$
 with $Es_v = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.03861616$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.08132796$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.07196647$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, \text{TBDY}) = 25.3952$
 $cc (5A.5, \text{TBDY}) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.04534935$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.09550849$

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08451471$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.16341093$$

$$M_u = M_{Rc}(4.14) = 2.3956E+008$$

$$u = s_u(4.1) = 1.0987593E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$V_{r1} = V_{Co1}((10.3), ASCE 41-17) = k_{nl} \cdot V_{Co10}$

$$V_{Co10} = 424229.688$$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} + f \cdot V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$M_u = 46.90894$$

$$V_u = 0.00016213$$

$$d = 0.8 \cdot h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 474729.557$$

where:

$V_{s1} = 335103.216$ is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

V_{s1} is multiplied by $Col1 = 1.00$

$$s/d = 0.20833333$$

$V_{s2} = 139626.34$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.4444$$

$$s = 100.00$$

V_{s2} is multiplied by $Col2 = 1.00$

$$s/d = 0.50$$

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 $V_f(\alpha, a_1)$, 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: $\alpha = 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

f_{fe} ((11-5), ACI 440) = 259.312

$$E_f = 64828.00$$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $V_r2 = 424229.688$
 $V_r2 = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 424229.688$
 $knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 46.90897$
 $Vu = 0.00016213$
 $d = 0.8 * h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$

where:

$V_{s1} = 335103.216$ is calculated for section web, with:

$d = 480.00$
 $Av = 157079.633$
 $fy = 444.4444$
 $s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.20833333$

$V_{s2} = 139626.34$ is calculated for section flange, with:

$d = 200.00$
 $Av = 157079.633$
 $fy = 444.4444$
 $s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.50$

$V_f ((11-3)-(11.4), ACI 440) = 293495.545$

$f = 0.95$, 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, $tf1 = NL * t / \text{NoDir} = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 557.00

$ffe ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$fe = 0.004$, from (11.6a), ACI 440

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rdcs

Constant Properties

Knowledge Factor, $\phi = 0.90$
 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, $f_s = f_{sm} = 444.4444$
 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, $f_s = 1.25 \cdot f_{sm} = 555.5556$
 #####
 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 = 1.26976
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i = 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

 Stepwise Properties

At local axis: 2
 EDGE -A-
 Shear Force, $V_a = 0.00016213$
 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 , $V_e/V_r = 0.66001628$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 279998.503$
 with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 4.2000E+008$
 $M_{u1+} = 4.2000E+008$, 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
 $M_{u1-} = 2.3956E+008$, 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.2000E+008$$

$M_{u2+} = 4.2000E+008$, 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

$M_{u2-} = 2.3956E+008$, 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:

$$u = 1.3683079E-005$$

$$M_u = 4.2000E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01648022$$

$$\phi_{cc} \text{ (5.4c), TBDY} = a_s e * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.10530374$$

where $\phi_f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$\phi_{fy} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{\text{conf,min}} = 122525.00$ 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).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00482813$$

$$psh,x ((5.4d), \text{TB DY}) = Lstir * Astir / (Asec * s) = 0.00482813$$

$$Lstir (\text{Length of stirrups along Y}) = 1460.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 237500.00$$

$$psh,y ((5.4d), \text{TB DY}) = Lstir * Astir / (Asec * s) = 0.00482813$$

$$Lstir (\text{Length of stirrups along X}) = 1460.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 237500.00$$

$$s = 100.00$$

$$fywe = 555.5556$$

$$fce = 20.00$$

$$\text{From } ((5.A5), \text{TB DY}), \text{TB DY: } cc = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$y1 = 0.0012967$$

$$sh1 = 0.0044814$$

$$ft1 = 373.4504$$

$$fy1 = 311.2087$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$su1 = 0.4 * esu1_nominal ((5.5), \text{TB DY}) = 0.032$$

From table 5A.1, TB DY: 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, TB DY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 311.2087$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0012967$$

$$sh2 = 0.0044814$$

$$ft2 = 373.4504$$

$$fy2 = 311.2087$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4 * esu2_nominal ((5.5), \text{TB DY}) = 0.032$$

From table 5A.1, TB DY: 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, TB DY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 311.2087$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0012967$$

$$shv = 0.0044814$$

$$ftv = 373.4504$$

$$fyv = 311.2087$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$suv = 0.4 * esuv_nominal ((5.5), \text{TB DY}) = 0.032$$

From table 5A.1, TB DY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TB DY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TB DY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 311.2087$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.19518711$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09267877$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.17271953$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$c_c (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.27144518$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12888764$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.24019969$$

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

--->

$$s_u (4.8) = 0.32821401$$

$$M_u = M_{Rc} (4.15) = 4.2000E+008$$

$$u = s_u (4.1) = 1.3683079E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0987593E-005$$

$$M_u = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01648022$$

$$w_e ((5.4c), TBDY) = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 600.00$$

hmax = 600.00
From EC8 A.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase = \text{Max}((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}} * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$
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.
 $A_{\text{conf,min}} = 122525.00$ 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$
 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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

s = 100.00
 $f_{ywe} = 555.5556$
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.0046976
c = confinement factor = 1.26976

$y1 = 0.0012967$
 $sh1 = 0.0044814$
 $ft1 = 373.4504$
 $fy1 = 311.2087$
 $su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: $esu1_{\text{nominal}} = 0.08$,

For calculation of $esu1_{\text{nominal}}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 311.2087$

with $Es1 = Es = 200000.00$

$y2 = 0.0012967$
 $sh2 = 0.0044814$
 $ft2 = 373.4504$
 $fy2 = 311.2087$
 $su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$su2 = 0.4 * esu2_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: $esu2_{\text{nominal}} = 0.08$,

For calculation of $esu2_{\text{nominal}}$ and $y2, sh2, ft2, fy2$, it is considered

characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 311.2087$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0012967$
 $sh_v = 0.0044814$
 $ft_v = 373.4504$
 $f_{y_v} = 311.2087$
 $s_{u_v} = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30$

$s_{u_v} = 0.4 \cdot e_{s_{u_v,nominal}} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{s_{u_v,nominal}} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{s_{u_v,nominal}}$ and y_v, sh_v, ft_v, f_{y_v} , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 311.2087$
 with $E_{sv} = E_s = 200000.00$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03861616$

$2 = A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08132796$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07196647$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 25.3952$

$cc (5A.5, TBDY) = 0.0046976$

$c = \text{confinement factor} = 1.26976$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04534935$

$2 = A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09550849$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08451471$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$s_u (4.9) = 0.16341093$

$M_u = M_{Rc} (4.14) = 2.3956E+008$

$u = s_u (4.1) = 1.0987593E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of M_{u2+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$u = 1.3683079E-005$

$M_u = 4.2000E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

$cc (5A.5, TBDY) = 0.002$

Final value of c_u : $c_u^* = \text{shear_factor} \cdot \text{Max}(c_u, cc) = 0.01648022$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01648022$

where ((5.4c), TBDY) = $a_{se} * sh_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.10530374$

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, $t_f = NL * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 122525.00$ is 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).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 100.00$

$f_{ywe} = 555.5556$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.0046976$

c = confinement factor = 1.26976

$y_1 = 0.0012967$

$sh_1 = 0.0044814$

$ft_1 = 373.4504$

$fy_1 = 311.2087$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$s_u1 = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,

For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $f_{sy1} = f_{s1}/1.2$, 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.

$$\text{with } f_{s1} = f_s = 311.2087$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.0012967$$

$$sh_2 = 0.0044814$$

$$ft_2 = 373.4504$$

$$fy_2 = 311.2087$$

$$s_u2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,

For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_{s2}/1.2$, 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.

$$\text{with } f_{s2} = f_s = 311.2087$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0012967$$

$$sh_v = 0.0044814$$

$$ft_v = 373.4504$$

$$fy_v = 311.2087$$

$$s_{u,v} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$s_{u,v} = 0.4 * e_{s_{u,v}_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_{u,v}_nominal} = 0.08$,

considering characteristic value $f_{s_{y,v}} = f_{s_{v}}/1.2$, from table 5.1, TBDY

For calculation of $e_{s_{u,v}_nominal}$ and y_v, sh_v, ft_v, fy_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, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s_{v}} = f_s = 311.2087$$

$$\text{with } E_{s_{v}} = E_s = 200000.00$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.19518711$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.09267877$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.17271953$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 25.3952$$

$$c_c (5A.5, TBDY) = 0.0046976$$

$$c = \text{confinement factor} = 1.26976$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.27144518$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.12888764$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.24019969$$

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

--->

$$s_u (4.8) = 0.32821401$$

$$\mu_u = M_{Rc} (4.15) = 4.2000E+008$$

$$u = s_u (4.1) = 1.3683079E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.0987593E-005$$

$$\mu_2 = 2.3956E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_0 \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear_factor} * \text{Max}(\mu_2, c_0) = 0.01648022$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_2 = 0.01648022$$

$$\mu_2 \text{ (5.4c), TBDY} = a_{se} * \mu_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.10530374$$

where $\mu_f = a_f * \mu_{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{fx} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{pf} = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$\mu_{fy} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{pf} = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.27151783$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (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.

$A_{conf,min} = 122525.00$ is 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).

$$\mu_{sh,min} = \text{Min}(\mu_{sh,x}, \mu_{sh,y}) = 0.00482813$$

$$\mu_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

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) = 0.00482813
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00
fywe = 555.5556
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.0046976
c = confinement factor = 1.26976

y1 = 0.0012967
sh1 = 0.0044814
ft1 = 373.4504
fy1 = 311.2087
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 311.2087

with Es1 = Es = 200000.00

y2 = 0.0012967
sh2 = 0.0044814
ft2 = 373.4504
fy2 = 311.2087
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 311.2087

with Es2 = Es = 200000.00

yv = 0.0012967
shv = 0.0044814
ftv = 373.4504
fyv = 311.2087
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 311.2087

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03861616

2 = Asl,com/(b*d)*(fs2/fc) = 0.08132796

v = Asl,mid/(b*d)*(fsv/fc) = 0.07196647

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 25.3952$
 $cc (5A.5, TBDY) = 0.0046976$
 $c = \text{confinement factor} = 1.26976$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04534935$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09550849$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08451471$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16341093$
 $Mu = MRc (4.14) = 2.3956E+008$
 $u = su (4.1) = 1.0987593E-005$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$
 $V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 424229.688$
 $knl = 1$ (zero step-static loading)

 NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
 where Vf is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 46.90488$
 $Vu = 0.00016213$
 $d = 0.8*h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
 where:
 $V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 335103.216$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, 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 $V_f(\theta, \alpha)$, 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, $V_{r2} = 424229.688$
 $V_{r2} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{CoI0}$
 $V_{CoI0} = 424229.688$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+ f \cdot V_f}$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 46.90486$
 $V_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 474729.557$
where:

$V_{s1} = 139626.34$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$

$V_{s2} = 335103.216$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.4444$
 $s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ 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: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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, $f_s = f_{sm} = 444.4444$

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

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 108192.18$

Shear Force, $V_2 = 2808.718$

Shear Force, $V_3 = -98.47243$

Axial Force, $F = -9398.91$

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 $u_{,R} = \gamma \cdot u = 0.03836462$

$u = \gamma \cdot u_p = 0.04262736$

- Calculation of γ -

$\gamma = (M_y \cdot L_s / 3) / E_{eff} = 0.00062736 ((4.29), \text{Biskinis Phd})$

My = 2.6300E+008
Ls = M/V (with Ls > 0.1*L and Ls < 2*L) = 300.00
From table 10.5, ASCE 41_17: Eleff = factor*Ec*Ig = 4.1921E+013
factor = 0.30
Ag = 237500.00
fc' = 20.00
N = 9398.91
Ec*Ig = 1.3974E+014

Calculation of Yielding Moment My

Calculation of ρ_y and My according to Annex 7 -

y = Min(ρ_{y_ten} , ρ_{y_com})
 ρ_{y_ten} = 3.6309447E-006
with ((10.1), ASCE 41-17) $\rho_y = \text{Min}(\rho_y, 1.25*\rho_y*(l_b/d)^{2/3}) = 248.9669$
d = 557.00
y = 0.38448755
A = 0.02987089
B = 0.01925313
with $\rho_{pt} = 0.01254381$
pc = 0.00595605
pv = 0.01109992
N = 9398.91
b = 250.00
" = 0.07719928
 ρ_{y_comp} = 8.1953602E-006
with ρ_{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 = $\rho_{pt} + \rho_{pc} + \rho_{pv} = 0.02959978$
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), $\rho_{efe} = 0.004$
 $\rho_{fu} = 0.01$
Ef = 64828.00
Ec = 21019.039
y = 0.38315868
A = 0.02940683
B = 0.01898202
with Es = 200000.00

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

- Calculation of ρ_p -

From table 10-8: $\rho_p = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$
shear control ratio $V_y E / V_{CoI} O E = 0.66001628$
d = 557.00
s = 0.00
 $t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$
Av = 78.53982, is the area of every stirrup
Lstir = 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 $f = 2 \cdot t_f / b_w$ 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.

$$N_{UD} = 9398.91$$

$$A_g = 237500.00$$

$$f_{cE} = 20.00$$

$$f_{yE} = f_{yI} = 0.00$$

$$p_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.02959978$$

$$b = 250.00$$

$$d = 557.00$$

$$f_{cE} = 20.00$$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)
