

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

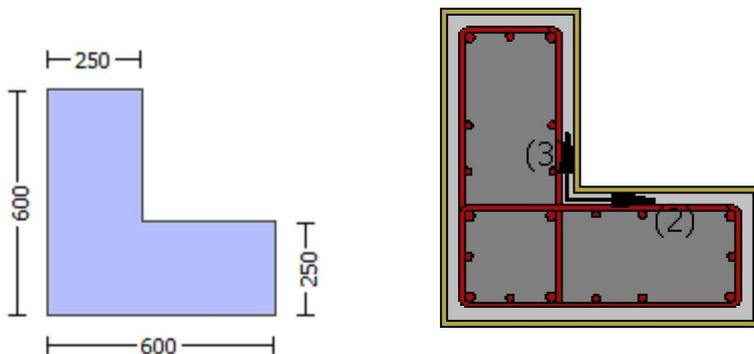
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

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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).

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

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

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Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -1.6425E+007$

Shear Force, $V_a = -5377.847$

EDGE -B-

Bending Moment, $M_b = 287980.756$

Shear Force, $V_b = 5377.847$

BOTH EDGES

Axial Force, $F = -9837.676$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 4737.522$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1900.664$

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

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

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.25$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 474293.855$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI} = 474293.855$

$V_{CoI} = 474293.855$

$k_n = 1.00$

$displacement_ductility_demand = 0.01511413$

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).

 $f = 1$ (normal-weight concrete)

$f_c' = 25.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/V_d = 4.00$

$\mu_u = 1.6425E+007$
 $V_u = 5377.847$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9837.676$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 534070.751$
 where:
 $V_{s1} = 157079.633$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 500.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 376991.118$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 500.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 V_f ((11-3)-(11.4), ACI 440) = 365392.00
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.00$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 f_{fe} ((11-5), ACI 440) = 328.00
 $E_f = 82000.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.009$
 From (11-11), ACI 440: $V_s + V_f \leq 398582.298$
 $b_w = 250.00$

displacement ductility demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 0.00010639$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.007039$ ((4.29), Biskinis Phd))
 $M_y = 3.7231E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3054.28
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 5.3849E+013$
 $\text{factor} = 0.30$
 $A_g = 237500.00$
 $f_c' = 33.00$
 $N = 9837.676$
 $E_c \cdot I_g = 1.7950E+014$

Calculation of Yielding Moment M_y

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

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.4405701E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 311.2112$
 $d = 558.00$

y = 0.37201073
A = 0.03418733
B = 0.02205932
with pt = 0.01362483
pc = 0.00594538
pv = 0.01439052
N = 9837.676
b = 250.00
" = 0.07706093
y_comp = 1.0794145E-005
with fc* (12.3, (ACI 440)) = 33.51939
fc = 33.00
fl = 0.77310341
b = bmax = 600.00
h = hmax = 600.00
Ag = 237500.00
g = pt + pc + pv = 0.03396073
rc = 40.00
Ae/Ac = 0.21429949
Effective FRP thickness, tf = NL*t*Cos(b1) = 1.00
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.009
Ef = 82000.00
Ec = 26999.444
y = 0.37101492
A = 0.03380294
B = 0.02183272
with Es = 200000.00

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 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

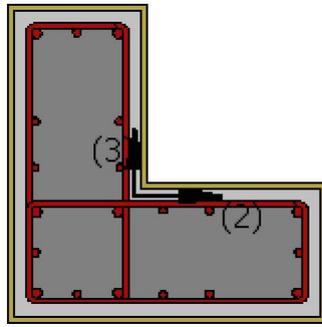
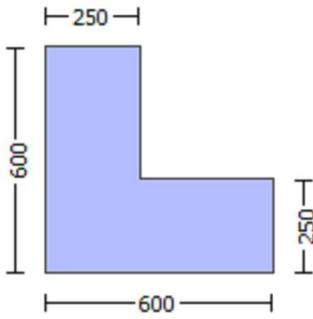
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

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, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

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Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.06737

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

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

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.14056349$

EDGE -B-

Shear Force, $V_b = -0.14056349$

BOTH EDGES

Axial Force, $F = -8933.736$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 4737.522$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{ten} = 1900.664$

-Compression: $As_{com} = 829.3805$

-Middle: $As_{mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.73796687$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 6.0294E+008$

$Mu_{1+} = 6.0294E+008$, 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

$Mu_{1-} = 3.2075E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 6.0294E+008$

$Mu_{2+} = 6.0294E+008$, 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

$Mu_{2-} = 3.2075E+008$, 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:

$\phi_u = 1.3372380E-005$

$M_u = 6.0294E+008$

with full section properties:

$b = 250.00$

$d = 558.00$

$d' = 43.00$

$v = 0.00194064$

$N = 8933.736$

$f_c = 33.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01247586$

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

From (5.4b), TBDY: $\phi_u = 0.01247586$

where $\phi_u = a_s e * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05035379$

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

$\phi_x = 0.04207769$

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), $\phi_{pf} = 2t_f / b_w = 0.008$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 720.2618$

$\phi_y = 0.04207769$

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

$a_f = 0.24098246$

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

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008$
 $bw = 250.00$
effective stress from (A.35), $ff,e = 720.2618$

$R = 40.00$
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.00$
 $f_u,f = 840.00$
 $E_f = 82000.00$
 $u,f = 0.015$

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

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

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

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

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

$s = 100.00$
 $f_{ywe} = 694.45$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$
 $c = \text{confinement factor} = 1.06737$

$y1 = 0.00140044$
 $sh1 = 0.0044814$
 $ft1 = 466.8167$
 $fy1 = 389.0139$
 $su1 = 0.00512$

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

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

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

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

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

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

with $fs1 = fs = 389.0139$

with $Es1 = Es = 200000.00$

$y2 = 0.00140044$
 $sh2 = 0.0044814$
 $ft2 = 466.8167$
 $fy2 = 389.0139$
 $su2 = 0.00512$

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

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

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

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

For calculation of $es_{u2_nominal}$ and y_2 , sh_2, ft_2, fy_2 , it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

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

with $fs_2 = fs = 389.0139$

with $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$s_{uv} = 0.00512$

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

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

$s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

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

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

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

with $f_{sv} = fs = 389.0139$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16061358$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07008593$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.1696398$

and confined core properties:

$b = 190.00$

$d = 528.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 35.22334$

$cc (5A.5, TBDY) = 0.00267374$

$c = \text{confinement factor} = 1.06737$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.22334125$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.097458$

$v = As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.23589266$

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

$s_u (4.8) = 0.31383738$

$M_u = MR_c (4.15) = 6.0294E+008$

$u = s_u (4.1) = 1.3372380E-005$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu_1 -

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

$u = 1.0927237E-005$

$M_u = 3.2075E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 42.00$

$v = 0.00081005$

$N = 8933.736$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$\text{we ((5.4c), TBDY) } = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

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

$$f_x = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

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

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).

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

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

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

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

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

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

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

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

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

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

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$f_{y1} = 389.0139$
 $s_{u1} = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30$
 $s_{u1} = 0.4 * e_{su1,nominal} ((5.5), TBDY) = 0.032$
 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.
 with $f_{s1} = f_s = 389.0139$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00140044$
 $sh_2 = 0.0044814$
 $ft_2 = 466.8167$
 $fy_2 = 389.0139$
 $s_{u2} = 0.00512$
 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
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$
 $s_{u2} = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$
 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.
 with $f_{s2} = f_s = 389.0139$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00140044$
 $sh_v = 0.0044814$
 $ft_v = 466.8167$
 $fy_v = 389.0139$
 $s_{uv} = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30$
 $s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,
 considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 389.0139$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0292549$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.06704247$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07081015$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07873215$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08315676$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $s_u (4.9) = 0.15879007$
 $M_u = M_{Rc} (4.14) = 3.2075E+008$
 $u = s_u (4.1) = 1.0927237E-005$

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:

$$\mu = 1.3372380E-005$$

$$\mu_{2+} = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_{cu}^* = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01247586$$

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

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.01247586$$

$$\mu_{cc} \text{ (5.4c), TBDY} = a_{se} * s_{h,min} * f_{y,we} / f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

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

$$f_x = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

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

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).

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

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

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

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

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

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

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

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

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

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

$$s = 100.00$$

$$fywe = 694.45$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs1 = fs = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs2 = fs = 389.0139$$

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

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

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

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

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

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

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

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

$$\text{with } fsv = fs = 389.0139$$

with $E_{sv} = E_s = 200000.00$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16061358$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07008593$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1696398$$

and confined core properties:

$$b = 190.00$$

$$d = 528.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 35.22334$$

$$c_c (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22334125$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.097458$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23589266$$

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

--->

$$s_u (4.8) = 0.31383738$$

$$\mu_u = M_{Rc} (4.15) = 6.0294E+008$$

$$u = s_u (4.1) = 1.3372380E-005$$

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

Calculation of μ_u

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

$$u = 1.0927237E-005$$

$$\mu_u = 3.2075E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 42.00$$

$$v = 0.00081005$$

$$N = 8933.736$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$w_e ((5.4c), TBDY) = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

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

$$f_x = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$f_y = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL*t*\text{Cos}(b1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

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

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).

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

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

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

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

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

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

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

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

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

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

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

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

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

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

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.

$$\text{with } fs1 = fs = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

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

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

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

$$\text{with } f_{s2} = f_s = 389.0139$$

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

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$s_{uv} = 0.00512$$

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

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

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

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

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

For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

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

$$\text{with } f_{sv} = f_s = 389.0139$$

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

$$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0292549$$

$$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.06704247$$

$$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$f_{cc} (5A.2, TBDY) = 35.22334$$

$$c_c (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03435585$$

$$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07873215$$

$$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.15879007$$

$$\mu_u = M_{Rc} (4.14) = 3.2075E+008$$

$$u = s_u (4.1) = 1.0927237E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$

$$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Co10}$$

$$V_{Co10} = 631439.816$$

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

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).

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

$$f_c' = 33.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$M/Vd = 2.00$
 $\mu_u = 90.31778$
 $V_u = 0.14056349$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8933.736$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$
 where:
 $V_{s1} = 418882.372$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.20833333$
 $V_{s2} = 174534.321$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 $V_f ((11-3)-(11.4), ACI 440) = 365392.00$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.00$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe} ((11-5), ACI 440) = 328.00$
 $E_f = 82000.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.009$
 From (11-11), ACI 440: $V_s + V_f \leq 457936.196$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 544688.006$
 $k_{nl} = 1$ (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).

$f_c = 33.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 330.5734$
 $V_u = 0.14056349$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8933.736$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$
 where:
 $V_{s1} = 418882.372$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.20833333$
 $V_{s2} = 174534.321$ is calculated for section flange, with:

$d = 200.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 $V_f((11-3)-(11.4), ACI 440) = 365392.00$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL*t/NoDir = 1.00$
 $dfv = d$ (figure 11.2, ACI 440) = 557.00
 $ffe((11-5), ACI 440) = 328.00$
 $E_f = 82000.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.009$
 From (11-11), ACI 440: $V_s + V_f \leq 457936.196$
 $bw = 250.00$

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

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

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 New material: Steel Strength, $f_s = 1.25*f_{sm} = 694.45$
 #####
 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 = 1.06737
 Element Length, $L = 3000.00$
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou, min} = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Dry properties (design values)
 Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$
Tensile Modulus, $E_f = 82000.00$
Elongation, $e_{fu} = 0.009$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 0.14056349$
EDGE -B-
Shear Force, $V_b = -0.14056349$
BOTH EDGES
Axial Force, $F = -8933.736$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_{lt} = 0.00$
-Compression: $As_{lc} = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 1900.664$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.73796687$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$
with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 6.0294E+008$
 $Mu_{1+} = 6.0294E+008$, 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
 $Mu_{1-} = 3.2075E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 6.0294E+008$
 $Mu_{2+} = 6.0294E+008$, 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
 $Mu_{2-} = 3.2075E+008$, 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 μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 1.3372380E-005$
 $Mu = 6.0294E+008$

with full section properties:

$b = 250.00$
 $d = 558.00$
 $d' = 43.00$
 $v = 0.00194064$
 $N = 8933.736$
 $f_c = 33.00$
 $\omega (5A.5, TBDY) = 0.002$
Final value of ω : $\omega^* = \text{shear_factor} * \text{Max}(\omega, \omega_c) = 0.01247586$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\omega = 0.01247586$
 $\omega_e ((5.4c), TBDY) = \omega * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$
where $f = \alpha * \rho * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

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), $p_f = 2t_f/b_w = 0.008$

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 720.2618$

$$f_y = 0.04207769$$

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), $p_f = 2t_f/b_w = 0.008$

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 720.2618$

$$R = 40.00$$

Effective FRP thickness, $t_f = N_L * t * \cos(b_1) = 1.00$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

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

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).

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

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

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

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

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

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

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

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

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

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

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

From ((5.A5), TBDY), TBDY: $c_c = 0.00267374$

$$c = \text{confinement factor} = 1.06737$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

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

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

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

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

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

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

with $fs1 = fs = 389.0139$

with $Es1 = Es = 200000.00$

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

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

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

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

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

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

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

with $fs2 = fs = 389.0139$

with $Es2 = Es = 200000.00$

$yv = 0.00140044$

$shv = 0.0044814$

$ftv = 466.8167$

$fyv = 389.0139$

$suv = 0.00512$

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

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

$suv = 0.4 \cdot esuv_nominal$ ((5.5), TBDY) = 0.032

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

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

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

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

with $fsv = fs = 389.0139$

with $Es = Es = 200000.00$

1 = $Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.16061358$

2 = $Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.07008593$

v = $Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.1696398$

and confined core properties:

$b = 190.00$

$d = 528.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 35.22334

cc (5A.5, TBDY) = 0.00267374

c = confinement factor = 1.06737

1 = $Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.22334125$

2 = $Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.097458$

v = $Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.23589266$

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) = 0.31383738

$Mu = MRc$ (4.15) = 6.0294E+008

$u = su$ (4.1) = 1.3372380E-005

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu1-

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

$$\mu = 1.0927237E-005$$

$$Mu = 3.2075E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 42.00$$

$$v = 0.00081005$$

$$N = 8933.736$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,\min} * f_{y,w} / f_{c,e} + \text{Min}(f_x, f_y) = 0.05035379$$

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

$$f_x = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

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

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).

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

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

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

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

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

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

s = 100.00
fywe = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00267374
c = confinement factor = 1.06737

y1 = 0.00140044
sh1 = 0.0044814
ft1 = 466.8167
fy1 = 389.0139
su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044
sh2 = 0.0044814
ft2 = 466.8167
fy2 = 389.0139
su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044
shv = 0.0044814
ftv = 466.8167
fyv = 389.0139
suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0292549

2 = Asl,com/(b*d)*(fs2/fc) = 0.06704247

v = Asl,mid/(b*d)*(fsv/fc) = 0.07081015

and confined core properties:

b = 540.00

$d = 527.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07873215$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08315676$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.15879007$
 $Mu = MRc (4.14) = 3.2075E+008$
 $u = su (4.1) = 1.0927237E-005$

 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:
 $u = 1.3372380E-005$
 $Mu = 6.0294E+008$

with full section properties:

$b = 250.00$
 $d = 558.00$
 $d' = 43.00$
 $v = 0.00194064$
 $N = 8933.736$
 $f_c = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01247586$
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$
 where $f = a_{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04207769$
 Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$
 $a_f = 0.24098246$
 with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$
 $b_{max} = 600.00$
 $h_{max} = 600.00$
 From EC8 A.4.4.3(6), $pf = 2t_f/b_w = 0.008$
 $b_w = 250.00$
 effective stress from (A.35), $f_{f,e} = 720.2618$

 $f_y = 0.04207769$
 Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$
 $a_f = 0.24098246$
 with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$
 $b_{max} = 600.00$
 $h_{max} = 600.00$
 From EC8 A.4.4.3(6), $pf = 2t_f/b_w = 0.008$
 $b_w = 250.00$
 effective stress from (A.35), $f_{f,e} = 720.2618$

 $R = 40.00$

Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{,f} = 0.015$

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

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).

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

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

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

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

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

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

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

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

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

with $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

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

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

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

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 389.0139$

with $Es_2 = Es = 200000.00$

$y_v = 0.00140044$
 $sh_v = 0.0044814$
 $ft_v = 466.8167$
 $fy_v = 389.0139$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 389.0139$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.16061358$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.07008593$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.1696398$

and confined core properties:

$b = 190.00$
 $d = 528.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.22334125$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.097458$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.23589266$

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
 --->

$su (4.8) = 0.31383738$
 $Mu = MRc (4.15) = 6.0294E+008$
 $u = su (4.1) = 1.3372380E-005$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu_2

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

$u = 1.0927237E-005$
 $Mu = 3.2075E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 42.00$
 $v = 0.00081005$
 $N = 8933.736$
 $fc = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01247586$

w_e ((5.4c), TBDY) = $a_{se} \cdot s_{h,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$
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)

$$f_x = 0.04207769$$

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), $p_f = 2t_f/b_w = 0.008$

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 720.2618$

$$f_y = 0.04207769$$

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), $p_f = 2t_f/b_w = 0.008$

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 720.2618$

$$R = 40.00$$

Effective FRP thickness, $t_f = N_L \cdot t \cdot \text{Cos}(b_1) = 1.00$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

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

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).

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

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

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

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

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

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

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

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

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

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

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

From ((5.A5), TBDY), TBDY: $c_c = 0.00267374$

$$c = \text{confinement factor} = 1.06737$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

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

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

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

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.

$$\text{with } f_{s1} = f_s = 389.0139$$

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

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$s_u2 = 0.00512$$

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.

$$\text{with } f_{s2} = f_s = 389.0139$$

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

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$s_{u,v} = 0.00512$$

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.

$$\text{with } f_{s_{v}} = f_s = 389.0139$$

$$\text{with } E_{s_{v}} = E_s = 200000.00$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.0292549$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.06704247$$

$$v = A_{s1,mid}/(b*d) * (f_{s_{v}}/f_c) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$f_{cc} (5A.2, TBDY) = 35.22334$$

$$c_c (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.03435585$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.07873215$$

$$v = A_{s1,mid}/(b*d) * (f_{s_{v}}/f_c) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$$s_u (4.9) = 0.15879007$$

$$\mu = M_{Rc} (4.14) = 3.2075E+008$$

$$u = s_u (4.1) = 1.0927237E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$
 $V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{\text{Col}0}$
 $V_{\text{Col}0} = 631439.816$
 $k_{nl} = 1$ (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).

 $k_c = 1$ (normal-weight concrete)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 90.32855$
 $V_u = 0.14056349$
 $d = 0.8 * h = 480.00$
 $N_u = 8933.736$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$
where:
 $V_{s1} = 174534.321$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 418882.372$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 365392.00$
 $f = 0.95$, 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 $(\cot \theta + \csc \theta) \sin \alpha_i$ 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: $\theta = 45^\circ$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
total thickness per orientation, $t_{f1} = N_L * t / N_{\text{Dir}} = 1.00$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe} ((11-5), \text{ACI } 440) = 328.00$
 $E_f = 82000.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.009$
From (11-11), ACI 440: $V_s + V_f \leq 457936.196$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{\text{Col}0}$
 $V_{\text{Col}0} = 544688.006$
 $k_{nl} = 1$ (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).

 $k_c = 1$ (normal-weight concrete)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00
Mu = 330.5627
Vu = 0.14056349
d = 0.8*h = 480.00
Nu = 8933.736
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 593416.693

where:

Vs1 = 174534.321 is calculated for section web, with:

d = 200.00
Av = 157079.633
fy = 555.56
s = 100.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.50

Vs2 = 418882.372 is calculated for section flange, with:

d = 480.00
Av = 157079.633
fy = 555.56
s = 100.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.20833333

Vf ((11-3)-(11.4), ACI 440) = 365392.00

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 Vf(θ , α), is implemented for every different fiber orientation ai, as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

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

Vf = Min(|Vf(45, θ_1)|, |Vf(-45, θ_1)|), with:

total thickness per orientation, tf1 = NL*t/NoDir = 1.00

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

ffe ((11-5), ACI 440) = 328.00

Ef = 82000.00

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

with fu = 0.009

From (11-11), ACI 440: Vs + Vf <= 457936.196

bw = 250.00

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

At local axis: 2

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

At local axis: 2

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\phi = 1.00$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, L = 3000.00
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_b/l_d = 0.30$
FRP Wrapping Data
Type: Carbon
Dry properties (design values)
Thickness, t = 1.00
Tensile Strength, $f_{fu} = 840.00$
Tensile Modulus, $E_f = 82000.00$
Elongation, $e_{fu} = 0.009$
Number of directions, NoDir = 1
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, M = -641478.12
Shear Force, V2 = -5377.847
Shear Force, V3 = 295.6742
Axial Force, F = -9837.676
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1900.664$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 2007.478$
Mean Diameter of Tension Reinforcement, $D_{bL} = 17.25$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.00500001$
 $u = y + p = 0.00500001$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00500001$ ((4.29), Biskinis Phd))
 $M_y = 3.7231E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2169.544
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.3849E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 33.00$
 $N = 9837.676$
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.4405701E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b/l_d)^{2/3}) = 311.2112$
 $d = 558.00$
 $y = 0.37201073$
 $A = 0.03418733$
 $B = 0.02205932$

with $p_t = 0.01362483$
 $p_c = 0.00594538$
 $p_v = 0.01439052$
 $N = 9837.676$
 $b = 250.00$
 $\rho = 0.07706093$
 $y_{comp} = 1.0794145E-005$
 with $f_c^* (12.3, (ACI 440)) = 33.51939$
 $f_c = 33.00$
 $f_l = 0.77310341$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $A_g = 237500.00$
 $g = p_t + p_c + p_v = 0.03396073$
 $r_c = 40.00$
 $A_e/A_c = 0.21429949$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.00$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.009$
 $E_f = 82000.00$
 $E_c = 26999.444$
 $y = 0.37101492$
 $A = 0.03380294$
 $B = 0.02183272$
 with $E_s = 200000.00$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 - Calculation of p -

 From table 10-8: $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$

shear control ratio $V_y E / V_{col} O E = 0.73796687$

$d = 558.00$

$s = 0.00$

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

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

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

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

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

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

$N_{UD} = 9837.676$

$A_g = 237500.00$

$f_c E = 33.00$

$f_{yt} E = f_{yl} E = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.03396073$

$b = 250.00$

$d = 558.00$

$f_c E = 33.00$

 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

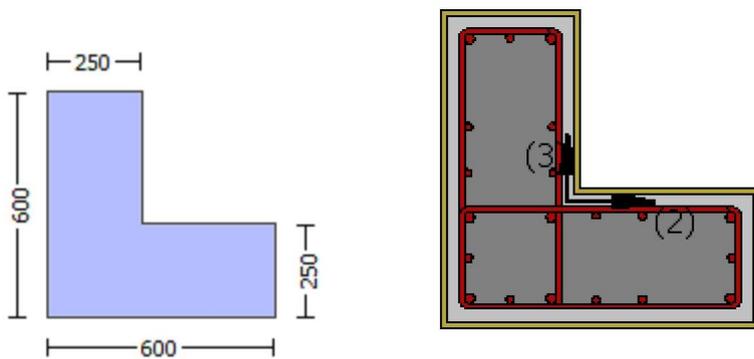
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

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: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of 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).

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

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

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

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, $M_a = -641478.12$

Shear Force, $V_a = 295.6742$

EDGE -B-

Bending Moment, $M_b = -244487.076$

Shear Force, $V_b = -295.6742$

BOTH EDGES

Axial Force, $F = -9837.676$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_{lt} = 0.00$

-Compression: $As_{lc} = 4737.522$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{l,ten} = 1900.664$

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

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

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.25$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 474293.855$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI0} = 474293.855$

$V_{CoI} = 474293.855$

$k_n = 1.00$

$displacement_ductility_demand = 0.00571194$

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)

$f_c' = 25.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 641478.12$

$V_u = 295.6742$

$d = 0.8 \cdot h = 480.00$

$N_u = 9837.676$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 534070.751$

where:

$V_{s1} = 376991.118$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

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

$s/d = 0.20833333$

$V_{s2} = 157079.633$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 $V_f((11-3)-(11.4), ACI 440) = 365392.00$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 $\ln(11.3) \sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where 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: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.00$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe}((11-5), ACI 440) = 328.00$
 $E_f = 82000.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.009$
 From (11-11), ACI 440: $V_s + V_f \leq 398582.298$
 $bw = 250.00$

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 $\theta = 2.8559754E-005$
 $y = (M_y * L_s / 3) / E_{eff} = 0.005000001$ ((4.29), Biskinis Phd)
 $M_y = 3.7231E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2169.544
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 5.3849E+013$
 $\text{factor} = 0.30$
 $A_g = 237500.00$
 $f_c' = 33.00$
 $N = 9837.676$
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment M_y

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

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.4405701E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$
 $d = 558.00$
 $y = 0.37201073$
 $A = 0.03418733$
 $B = 0.02205932$
 with $pt = 0.01362483$
 $pc = 0.00594538$
 $pv = 0.01439052$
 $N = 9837.676$
 $b = 250.00$
 $\theta = 0.07706093$
 $y_{comp} = 1.0794145E-005$
 with $f_c'((12.3), (ACI 440)) = 33.51939$
 $f_c = 33.00$
 $f_l = 0.77310341$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $A_g = 237500.00$
 $g = pt + pc + pv = 0.03396073$
 $rc = 40.00$

$$A_e/A_c = 0.21429949$$

$$\text{Effective FRP thickness, } t_f = NL \cdot t \cdot \cos(b_1) = 1.00$$

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

$$f_u = 0.009$$

$$E_f = 82000.00$$

$$E_c = 26999.444$$

$$y = 0.37101492$$

$$A = 0.03380294$$

$$B = 0.02183272$$

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: (a)

Calculation No. 4

column C1, Floor 1

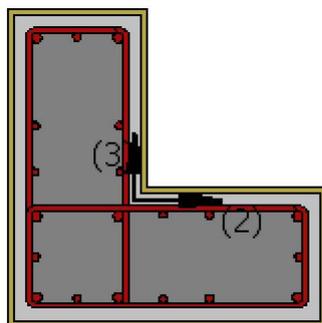
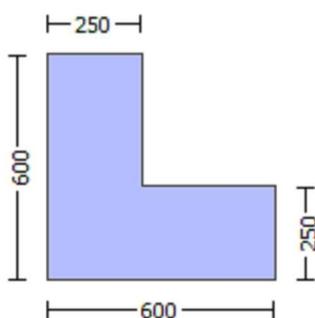
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: Start

Local Axis: (3)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

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 = 1.06737
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
FRP Wrapping Data
Type: Carbon
Dry properties (design values)
Thickness, $t = 1.00$
Tensile Strength, $f_{fu} = 840.00$
Tensile Modulus, $E_f = 82000.00$
Elongation, $e_{fu} = 0.009$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 0.14056349$
EDGE -B-
Shear Force, $V_b = -0.14056349$
BOTH EDGES
Axial Force, $F = -8933.736$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1900.664$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.73796687$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 6.0294E+008$
 $M_{u1+} = 6.0294E+008$, 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
 $M_{u1-} = 3.2075E+008$, 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 6.0294E+008$$

$M_{u2+} = 6.0294E+008$, 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

$M_{u2-} = 3.2075E+008$, 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:

$$\phi_u = 1.3372380E-005$$

$$M_u = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01247586$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01247586$$

$$\omega_e (\text{5.4c), TBDY}) = a_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05035379$$

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

$$\phi_x = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$\phi_y = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

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

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).

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

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

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

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

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

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

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

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

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

$$su_1 = 0.4 * esu_1_{nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_1_{nominal} = 0.08,$$

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

$$\text{with } fs_1 = fs = 389.0139$$

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

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

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

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

$$su_2 = 0.4 * esu_2_{nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_2_{nominal} = 0.08,$$

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

$$\text{with } fs_2 = fs = 389.0139$$

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

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$suv = 0.00512$$

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

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

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

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

considering characteristic value fsy_v = fs_v/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and y_v, sh_v, ft_v, fy_v, it is considered
characteristic value fsy_v = fs_v/1.2, from table 5.1, TBDY.

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

$$\text{with } fs_v = fs = 389.0139$$

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16061358$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07008593$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1696398$$

and confined core properties:

$$b = 190.00$$

$$d = 528.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 35.22334$$

$$c_c (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22334125$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.097458$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23589266$$

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

--->

$$s_u (4.8) = 0.31383738$$

$$\mu_u = M_{Rc} (4.15) = 6.0294E+008$$

$$u = s_u (4.1) = 1.3372380E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{u1} -

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

$$u = 1.0927237E-005$$

$$\mu_u = 3.2075E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 42.00$$

$$v = 0.00081005$$

$$N = 8933.736$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

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

$$f_x = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$f_y = 0.04207769$$

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

$$a_f = 0.24098246$$

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

bmax = 600.00
hmax = 600.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008$
bw = 250.00
effective stress from (A.35), $ff,e = 720.2618$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.00$
 $f_{u,f} = 840.00$
 $E_f = 82000.00$
 $u_{,f} = 0.015$

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

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

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

psh_x ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$
 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
 $f_{ywe} = 694.45$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$
c = confinement factor = 1.06737

$y_1 = 0.00140044$
 $sh_1 = 0.0044814$

$ft_1 = 466.8167$
 $fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

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

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

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

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

with $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$
 $sh_2 = 0.0044814$

$ft_2 = 466.8167$
 $fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

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

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

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

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

$$\text{with } fs_2 = fs = 389.0139$$

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

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

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

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

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

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

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

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

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

$$\text{with } fsv = fs = 389.0139$$

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

$$1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.0292549$$

$$2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.06704247$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$fcc (5A.2, TBDY) = 35.22334$$

$$cc (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.03435585$$

$$2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.07873215$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.15879007$$

$$\mu_u = MRc (4.14) = 3.2075E+008$$

$$u = su (4.1) = 1.0927237E-005$$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of μ_{u2+}

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

$$u = 1.3372380E-005$$

$$\mu_u = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$\text{we ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

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

$$f_x = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

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

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).

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

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

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

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

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

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

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

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

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

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

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$f_{y1} = 389.0139$
 $s_{u1} = 0.00512$
 using (30) in Biskinis/Fardis (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, f_{y1} , it is considered
 characteristic value $f_{s1} = f_s/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s1} = f_s = 389.0139$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00140044$
 $sh_2 = 0.0044814$
 $ft_2 = 466.8167$
 $f_{y2} = 389.0139$
 $s_{u2} = 0.00512$
 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, f_{y2} , it is considered
 characteristic value $f_{s2} = f_s/1.2$, from table 5.1, TBDY.
 y_2, sh_2, ft_2, f_{y2} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 389.0139$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00140044$
 $sh_v = 0.0044814$
 $ft_v = 466.8167$
 $f_{yv} = 389.0139$
 $s_{uv} = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,
 considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $e_{suv_nominal}$ and y_v, sh_v, ft_v, f_{yv} , it is considered
 characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 389.0139$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16061358$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07008593$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1696398$
 and confined core properties:
 $b = 190.00$
 $d = 528.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22334125$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.097458$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23589266$
 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
 --->
 $s_u (4.8) = 0.31383738$

$$\begin{aligned} \mu_u &= M/R_c (4.15) = 6.0294E+008 \\ u &= s_u (4.1) = 1.3372380E-005 \end{aligned}$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_u

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

$$\begin{aligned} u &= 1.0927237E-005 \\ \mu_u &= 3.2075E+008 \end{aligned}$$

with full section properties:

$$\begin{aligned} b &= 600.00 \\ d &= 557.00 \\ d' &= 42.00 \\ v &= 0.00081005 \\ N &= 8933.736 \\ f_c &= 33.00 \\ c_o (5A.5, TBDY) &= 0.002 \\ \text{Final value of } \mu_u: \mu_u^* &= \text{shear_factor} * \text{Max}(\mu_u, c_c) = 0.01247586 \\ \text{The Shear_factor is considered equal to 1 (pure moment strength)} \\ \text{From (5.4b), TBDY: } \mu_u &= 0.01247586 \\ \mu_{we} ((5.4c), TBDY) &= a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379 \\ \text{where } f &= a_f * p_f * f_{fe}/f_{ce} \text{ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)} \end{aligned}$$

$$f_x = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$f_y = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

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

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.

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

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

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

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

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

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

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 100.00

fywe = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00267374

c = confinement factor = 1.06737

y1 = 0.00140044

sh1 = 0.0044814

ft1 = 466.8167

fy1 = 389.0139

su1 = 0.00512

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

lo/lou,min = lb/l_d = 0.30

su1 = 0.4*esu1_nominal ((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 = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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

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

su2 = 0.4*esu2_nominal ((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 = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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

lo/lou,min = lb/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 $f_{sv} = f_s = 389.0139$

with $E_{sv} = E_s = 200000.00$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0292549$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.06704247$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07081015$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 12.00$

$f_{cc} (5A.2, TBDY) = 35.22334$

$cc (5A.5, TBDY) = 0.00267374$

$c = \text{confinement factor} = 1.06737$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03435585$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07873215$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08315676$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$\mu_u (4.9) = 0.15879007$

$\mu_u = MR_c (4.14) = 3.2075E+008$

$u = \mu_u (4.1) = 1.0927237E-005$

Calculation of ratio lb/d

Inadequate Lap Length with $lb/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$

$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Co10}$

$V_{Co10} = 631439.816$

$k_{nl} = 1$ (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)

$f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$M/d = 2.00$

$\mu_u = 90.31778$

$V_u = 0.14056349$

$d = 0.8 \cdot h = 480.00$

$N_u = 8933.736$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$

where:

$V_{s1} = 418882.372$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.20833333$

$V_{s2} = 174534.321$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.50$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 365392.00$$

$f = 0.95$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$

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

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.00$

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

f_{fe} ((11-5), ACI 440) = 328.00

$E_f = 82000.00$

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

with $f_u = 0.009$

From (11-11), ACI 440: $V_s + V_f \leq 457936.196$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l * V_{Col0}$

$V_{Col0} = 544688.006$

$k_n l = 1$ (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)

$f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 330.5734$

$\nu_u = 0.14056349$

$d = 0.8 * h = 480.00$

$N_u = 8933.736$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$

where:

$V_{s1} = 418882.372$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.20833333$

$V_{s2} = 174534.321$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.50$

V_f ((11-3)-(11.4), ACI 440) = 365392.00

$f = 0.95$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$

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

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.00$

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

f_{fe} ((11-5), ACI 440) = 328.00

$E_f = 82000.00$

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

with $f_u = 0.009$

From (11-11), ACI 440: $V_s + V_f \leq 457936.196$

bw = 250.00

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

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

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

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

#####

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 = 1.06737

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

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, $V_a = 0.14056349$

EDGE -B-

Shear Force, $V_b = -0.14056349$

BOTH EDGES

Axial Force, $F = -8933.736$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 4737.522$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $Asl,ten = 1900.664$
-Compression: $Asl,com = 829.3805$
-Middle: $Asl,mid = 2007.478$

Calculation of Shear Capacity ratio, $Ve/Vr = 0.73796687$

Member Controlled by Flexure ($Ve/Vr < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $Ve = (Mpr1 + Mpr2)/ln = 401961.704$

with
 $Mpr1 = \text{Max}(Mu1+, Mu1-) = 6.0294E+008$
 $Mu1+ = 6.0294E+008$, 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
 $Mu1- = 3.2075E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $Mpr2 = \text{Max}(Mu2+, Mu2-) = 6.0294E+008$
 $Mu2+ = 6.0294E+008$, 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
 $Mu2- = 3.2075E+008$, 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 u according to 4.1, Biskinis/Fardis 2013:

$u = 1.3372380E-005$
 $Mu = 6.0294E+008$

with full section properties:

$b = 250.00$
 $d = 558.00$
 $d' = 43.00$
 $v = 0.00194064$
 $N = 8933.736$
 $fc = 33.00$
 $co (5A.5, TBDY) = 0.002$
Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $cu = 0.01247586$
 $w_e ((5.4c), TBDY) = ase * sh, \text{min} * fywe / fce + \text{Min}(fx, fy) = 0.05035379$
where $f = af * pf * ffe / fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$fx = 0.04207769$

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), $pf = 2tf/bw = 0.008$

$bw = 250.00$

effective stress from (A.35), $ff,e = 720.2618$

$fy = 0.04207769$

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), $pf = 2tf/bw = 0.008$

$bw = 250.00$

effective stress from (A.35), $ff,e = 720.2618$

$R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.00$

$f_{u,f} = 840.00$
 $E_f = 82000.00$
 $u_{,f} = 0.015$

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

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).

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

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

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

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

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

$su_1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$

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

For calculation of $esu1_nominal$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

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

with $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

$su_2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$

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

For calculation of $esu2_nominal$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 389.0139$

with $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$shv = 0.0044814$
 $ftv = 466.8167$
 $fyv = 389.0139$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.30$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv , shv,ftv,fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 389.0139$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.16061358$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.07008593$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.1696398$
 and confined core properties:
 $b = 190.00$
 $d = 528.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.22334125$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.097458$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.23589266$
 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
 --->
 $su (4.8) = 0.31383738$
 $Mu = MRc (4.15) = 6.0294E+008$
 $u = su (4.1) = 1.3372380E-005$

 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:

$u = 1.0927237E-005$
 $Mu = 3.2075E+008$

 with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 42.00$
 $v = 0.00081005$
 $N = 8933.736$
 $fc = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.01247586$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01247586$
 $ve ((5.4c), TBDY) = ase * sh,min*fywe/fce + Min(fx, fy) = 0.05035379$

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

$$fx = 0.04207769$$

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), $pf = 2tf/bw = 0.008$

$$bw = 250.00$$

effective stress from (A.35), $ffe = 720.2618$

$$fy = 0.04207769$$

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), $pf = 2tf/bw = 0.008$

$$bw = 250.00$$

effective stress from (A.35), $ffe = 720.2618$

$$R = 40.00$$

Effective FRP thickness, $tf = NL \cdot t \cdot \cos(b1) = 1.00$

$$fu,f = 840.00$$

$$Ef = 82000.00$$

$$u,f = 0.015$$

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

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).

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

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

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

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

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

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

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

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

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

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

$$s = 100.00$$

$$fywe = 694.45$$

$$fce = 33.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

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

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

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

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

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

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

$$\text{with } fs1 = fs = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

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

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

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

$$\text{with } fs2 = fs = 389.0139$$

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

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

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

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

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

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.

$$\text{with } fsv = fs = 389.0139$$

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

$$1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.0292549$$

$$2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.06704247$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$fcc (5A.2, TBDY) = 35.22334$$

$$cc (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.03435585$$

$$2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.07873215$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.15879007$$

$$Mu = MRc (4.14) = 3.2075E+008$$

$$u = su (4.1) = 1.0927237E-005$$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu2+

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

$$\mu = 1.3372380E-005$$

$$Mu = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,\min} * f_{y,w} / f_{c,e} + \text{Min}(f_x, f_y) = 0.05035379$$

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

$$f_x = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

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

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).

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

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

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

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

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

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

s = 100.00
fywe = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00267374
c = confinement factor = 1.06737

y1 = 0.00140044
sh1 = 0.0044814
ft1 = 466.8167
fy1 = 389.0139
su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044
sh2 = 0.0044814
ft2 = 466.8167
fy2 = 389.0139
su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044
shv = 0.0044814
ftv = 466.8167
fyv = 389.0139
suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16061358

2 = Asl,com/(b*d)*(fs2/fc) = 0.07008593

v = Asl,mid/(b*d)*(fsv/fc) = 0.1696398

and confined core properties:

b = 190.00

$d = 528.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22334125$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.097458$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23589266$
 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
 --->

$s_u (4.8) = 0.31383738$
 $\mu_u = MR_c (4.15) = 6.0294E+008$
 $u = s_u (4.1) = 1.3372380E-005$

 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 u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.0927237E-005$
 $\mu_u = 3.2075E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 42.00$
 $v = 0.00081005$
 $N = 8933.736$
 $f_c = 33.00$
 $cc (5A.5, TBDY) = 0.002$
 Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, cc) = 0.01247586$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $c_u = 0.01247586$
 $w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$
 where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04207769$
 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), $p_f = 2t_f/b_w = 0.008$
 $b_w = 250.00$
 effective stress from (A.35), $f_{f,e} = 720.2618$

$f_y = 0.04207769$
 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), $p_f = 2t_f/b_w = 0.008$
 $b_w = 250.00$
 effective stress from (A.35), $f_{f,e} = 720.2618$

R = 40.00

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{,f} = 0.015$

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

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)

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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).

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

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

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

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

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

$su_1 = 0.4 \cdot esu1_nominal$ ((5.5), TBDY) = 0.032

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

For calculation of $esu1_nominal$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

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

with $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

$su_2 = 0.4 \cdot esu2_nominal$ ((5.5), TBDY) = 0.032

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

For calculation of $esu2_nominal$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

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

with $f_{s2} = f_s = 389.0139$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00140044$
 $sh_v = 0.0044814$
 $ft_v = 466.8167$
 $fy_v = 389.0139$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 389.0139$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.0292549$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.06704247$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07081015$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.03435585$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07873215$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.08315676$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

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

$su (4.9) = 0.15879007$
 $\mu = MR_c (4.14) = 3.2075E+008$
 $u = su (4.1) = 1.0927237E-005$

 Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$
 $V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{ColO}$
 $V_{ColO} = 631439.816$
 $knl = 1$ (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)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu = 90.32855$
 $V_u = 0.14056349$
 $d = 0.8 * h = 480.00$
 $N_u = 8933.736$
 $A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$

where:

$V_{s1} = 174534.321$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.50$

$V_{s2} = 418882.372$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.20833333$

V_f ((11-3)-(11.4), ACI 440) = 365392.00

$f = 0.95$, 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: $\theta = 45^\circ$

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

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.00$

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

f_{fe} ((11-5), ACI 440) = 328.00

$E_f = 82000.00$

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

with $f_u = 0.009$

From (11-11), ACI 440: $V_s + V_f \leq 457936.196$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$

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

$V_{Col0} = 544688.006$

$k_n l = 1$ (zero step-static loading)

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

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

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

$f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 330.5627$

$\nu_u = 0.14056349$

$d = 0.8 \cdot h = 480.00$

$N_u = 8933.736$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$

where:

$V_{s1} = 174534.321$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.50$

$V_{s2} = 418882.372$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.20833333$

Vf ((11-3)-(11.4), ACI 440) = 365392.00

f = 0.95, for fully-wrapped sections

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

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

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

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

Vf = Min(|Vf(45, 1)|, |Vf(-45, a1)|), with:

total thickness per orientation, tf1 = NL*t/NoDir = 1.00

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

ffe ((11-5), ACI 440) = 328.00

Ef = 82000.00

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

with fu = 0.009

From (11-11), ACI 440: Vs + Vf <= 457936.196

bw = 250.00

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

At local axis: 2

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

At local axis: 3

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

Number of directions, NoDir = 1

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, NL = 1

Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, $M = -1.6425E+007$
Shear Force, $V2 = -5377.847$
Shear Force, $V3 = 295.6742$
Axial Force, $F = -9837.676$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{,ten} = 1900.664$
-Compression: $As_{,com} = 829.3805$
-Middle: $As_{,mid} = 2007.478$
Mean Diameter of Tension Reinforcement, $Db_L = 17.25$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.007039$
 $u = y + p = 0.007039$

- Calculation of y -

$y = (My * Ls / 3) / Eleff = 0.007039$ ((4.29), Biskinis Phd)
 $My = 3.7231E+008$
 $Ls = M/V$ (with $Ls > 0.1 * L$ and $Ls < 2 * L$) = 3054.28
From table 10.5, ASCE 41_17: $Eleff = factor * Ec * I_g = 5.3849E+013$
 $factor = 0.30$
 $Ag = 237500.00$
 $fc' = 33.00$
 $N = 9837.676$
 $Ec * I_g = 1.7950E+014$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

$y = \text{Min}(y_{,ten}, y_{,com})$
 $y_{,ten} = 4.4405701E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$
 $d = 558.00$
 $y = 0.37201073$
 $A = 0.03418733$
 $B = 0.02205932$
with $pt = 0.01362483$
 $pc = 0.00594538$
 $pv = 0.01439052$
 $N = 9837.676$
 $b = 250.00$
 $" = 0.07706093$
 $y_{,comp} = 1.0794145E-005$
with fc^* (12.3, (ACI 440)) = 33.51939
 $fc = 33.00$
 $fl = 0.77310341$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $Ag = 237500.00$
 $g = pt + pc + pv = 0.03396073$
 $rc = 40.00$
 $Ae / Ac = 0.21429949$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.00$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.009$
 $E_f = 82000.00$
 $E_c = 26999.444$
 $y = 0.37101492$

A = 0.03380294
B = 0.02183272
with Es = 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 $V_{yE}/V_{CoIE} = 0.73796687$

$d = 558.00$

$s = 0.00$

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

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

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

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

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

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

$NUD = 9837.676$

$A_g = 237500.00$

$f_{cE} = 33.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.03396073$

$b = 250.00$

$d = 558.00$

$f_{cE} = 33.00$

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

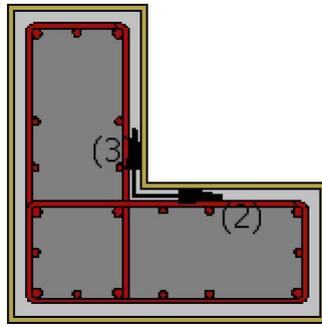
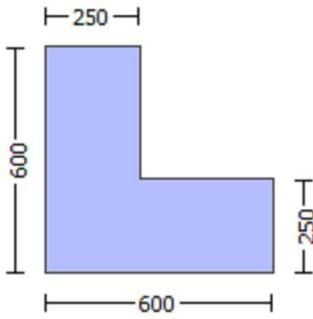
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



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

At local axis: 2

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of 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).

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

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

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -1.6425E+007$

Shear Force, $V_a = -5377.847$

EDGE -B-

Bending Moment, $M_b = 287980.756$

Shear Force, $V_b = 5377.847$

BOTH EDGES

Axial Force, $F = -9837.676$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 4737.522$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{s,ten} = 1900.664$

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

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

Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 17.25$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 550005.412$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{Co10} = 550005.412$

$V_{Co10} = 550005.412$

$k_n = 1.00$

displacement_ductility_demand = 0.06908498

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)

$f_c' = 25.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 287980.756$

$V_u = 5377.847$

$d = 0.8 \cdot h = 480.00$

$N_u = 9837.676$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 534070.751$

where:

$V_{s1} = 157079.633$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

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

$s/d = 0.50$

$V_{s2} = 376991.118$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

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

$s/d = 0.20833333$

V_f ((11-3)-(11.4), ACI 440) = 365392.00

$f = 0.95$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$

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

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.00$

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

f_{fe} ((11-5), ACI 440) = 328.00

$E_f = 82000.00$

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

with $f_u = 0.009$

From (11-11), ACI 440: $V_s + V_f \leq 398582.298$

$b_w = 250.00$

displacement_ductility_demand is calculated as ϕ / y

- Calculation of ϕ / y for END B -
for rotation axis 3 and integ. section (b)

From analysis, chord rotation = $4.7764689E-005$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00069139$ ((4.29), Biskinis Phd))
 $M_y = 3.7231E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.3849E+013$
factor = 0.30
Ag = 237500.00
fc' = 33.00
N = 9837.676
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment M_y

Calculation of ϕ and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.4405701E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 311.2112$
d = 558.00
 $y = 0.37201073$
A = 0.03418733
B = 0.02205932
with pt = 0.01362483
pc = 0.00594538
pv = 0.01439052
N = 9837.676
b = 250.00
" = 0.07706093
 $y_{comp} = 1.0794145E-005$
with fc' (12.3, (ACI 440)) = 33.51939
fc = 33.00
fl = 0.77310341
b = bmax = 600.00
h = hmax = 600.00
Ag = 237500.00
g = pt + pc + pv = 0.03396073
rc = 40.00
Ae/Ac = 0.21429949
Effective FRP thickness, tf = $NL * t * \text{Cos}(b1) = 1.00$
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.009
Ef = 82000.00
Ec = 26999.444
 $y = 0.37101492$
A = 0.03380294
B = 0.02183272
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: 2
Integration Section: (b)

Calculation No. 6

column C1, Floor 1

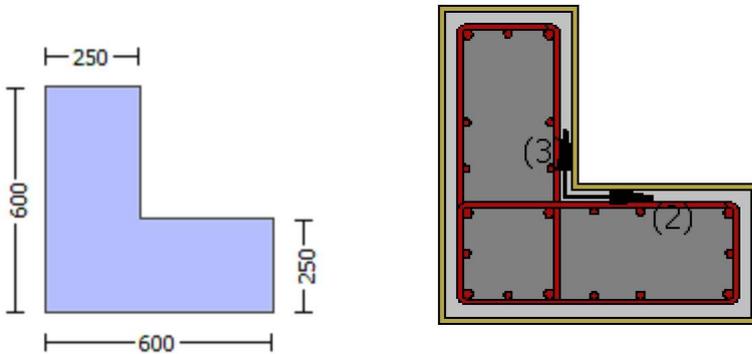
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

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: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

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 = 1.06737

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
FRP Wrapping Data
Type: Carbon
Dry properties (design values)
Thickness, $t = 1.00$
Tensile Strength, $f_{fu} = 840.00$
Tensile Modulus, $E_f = 82000.00$
Elongation, $e_{fu} = 0.009$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 0.14056349$
EDGE -B-
Shear Force, $V_b = -0.14056349$
BOTH EDGES
Axial Force, $F = -8933.736$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 1900.664$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 2007.478$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.73796687$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 6.0294E+008$
 $Mu_{1+} = 6.0294E+008$, 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
 $Mu_{1-} = 3.2075E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 6.0294E+008$
 $Mu_{2+} = 6.0294E+008$, 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
 $Mu_{2-} = 3.2075E+008$, 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:
 $\phi_u = 1.3372380E-005$
 $M_u = 6.0294E+008$

with full section properties:
 $b = 250.00$
 $d = 558.00$
 $d' = 43.00$
 $v = 0.00194064$

$$N = 8933.736$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$\text{we ((5.4c), TBDY)} = a_s e^* \text{ sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

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

$$f_x = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

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

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).

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

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

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

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

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

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

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

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

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

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

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs1 = fs = 389.0139$$

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

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

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

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

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

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

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

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

$$\text{with } fs2 = fs = 389.0139$$

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

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

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

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

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

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

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

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

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

$$\text{with } fsv = fs = 389.0139$$

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.16061358$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.07008593$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.1696398$$

and confined core properties:

$$b = 190.00$$

$$d = 528.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 35.22334$$

$$cc (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.22334125$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.097458$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.23589266$$

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) = 0.31383738
Mu = MRc (4.15) = 6.0294E+008
u = su (4.1) = 1.3372380E-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 = 1.0927237E-005
Mu = 3.2075E+008

with full section properties:

b = 600.00
d = 557.00
d' = 42.00
v = 0.00081005
N = 8933.736
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01247586
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01247586
ve ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.05035379
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.04207769

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

af = 0.24098246

with Unconfined area = ((bmax-2R)^2 + (hmax-2R)^2)/3 = 57233.333

bmax = 600.00

hmax = 600.00

From EC8 A4.4.3(6), pf = 2tf/bw = 0.008

bw = 250.00

effective stress from (A.35), ff,e = 720.2618

fy = 0.04207769

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

af = 0.24098246

with Unconfined area = ((bmax-2R)^2 + (hmax-2R)^2)/3 = 0.00

bmax = 600.00

hmax = 600.00

From EC8 A4.4.3(6), pf = 2tf/bw = 0.008

bw = 250.00

effective stress from (A.35), ff,e = 720.2618

R = 40.00

Effective FRP thickness, tf = NL*t*Cos(b1) = 1.00

fu,f = 840.00

Ef = 82000.00

u,f = 0.015

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.27151783

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

Aconf,max = 169100.00 is the confined core area at levels of member with hoops and

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

Aconf,min = 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).

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

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

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

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

 $s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

$c = \text{confinement factor} = 1.06737$

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

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

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

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

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

with $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

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

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

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

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 389.0139$

with $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

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

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

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

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

considering characteristic value $fsy_v = fs_v/1.2$, from table 5.1, TBDY

For calculation of $esu_{v,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

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

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

with $f_{sv} = f_s = 389.0139$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0292549$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.06704247$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07081015$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 12.00$

$f_{cc} (5A.2, TBDY) = 35.22334$

$cc (5A.5, TBDY) = 0.00267374$

$c = \text{confinement factor} = 1.06737$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03435585$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07873215$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08315676$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.15879007$

$Mu = MRc (4.14) = 3.2075E+008$

$u = su (4.1) = 1.0927237E-005$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu_{2+}

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

$u = 1.3372380E-005$

$Mu = 6.0294E+008$

with full section properties:

$b = 250.00$

$d = 558.00$

$d' = 43.00$

$v = 0.00194064$

$N = 8933.736$

$f_c = 33.00$

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

Final value of cu : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01247586$

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

From (5.4b), TBDY: $cu = 0.01247586$

$w_e ((5.4c), TBDY) = ase \cdot sh_{min} \cdot fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.05035379$

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

 $fx = 0.04207769$

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), $pf = 2tf/bw = 0.008$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 720.2618$

 $fy = 0.04207769$

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

af = 0.24098246
with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$
bmax = 600.00
hmax = 600.00
From EC8 A.4.4.3(6), pf = $2t_f/b_w = 0.008$
bw = 250.00
effective stress from (A.35), ff,e = 720.2618

R = 40.00
Effective FRP thickness, tf = $NL*t*Cos(b1) = 1.00$
fu,f = 840.00
Ef = 82000.00
u,f = 0.015

ase = $Max(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.27151783$
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

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

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

Aconf,min = 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 = $Min(psh,x, psh,y) = 0.00482813$

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

psh,x ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$
Lstir (Length of stirrups along Y) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00
fywe = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00267374
c = confinement factor = 1.06737

y1 = 0.00140044
sh1 = 0.0044814

ft1 = 466.8167
fy1 = 389.0139

su1 = 0.00512

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

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

su1 = $0.4*es_{1_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: es1_nominal = 0.08,

For calculation of es1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = $f_s/1.2$, from table 5.1, TBDY.

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

with fs1 = $f_s = 389.0139$

with Es1 = $E_s = 200000.00$

y2 = 0.00140044
sh2 = 0.0044814

ft2 = 466.8167
fy2 = 389.0139

su2 = 0.00512

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

Shear_factor = 1.00

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

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

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

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

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

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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

lo/lou,min = lb/ld = 0.30

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

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

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

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

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

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16061358

2 = Asl,com/(b*d)*(fs2/fc) = 0.07008593

v = Asl,mid/(b*d)*(fsv/fc) = 0.1696398

and confined core properties:

b = 190.00

d = 528.00

d' = 13.00

fcc (5A.2, TBDY) = 35.22334

cc (5A.5, TBDY) = 0.00267374

c = confinement factor = 1.06737

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22334125

2 = Asl,com/(b*d)*(fs2/fc) = 0.097458

v = Asl,mid/(b*d)*(fsv/fc) = 0.23589266

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) = 0.31383738

Mu = MRc (4.15) = 6.0294E+008

u = su (4.1) = 1.3372380E-005

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu2-

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

u = 1.0927237E-005

Mu = 3.2075E+008

with full section properties:

b = 600.00

d = 557.00

d' = 42.00

v = 0.00081005

N = 8933.736

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$

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

From (5.4b), TBDY: $cu = 0.01247586$

we ((5.4c), TBDY) = $ase * sh_{,min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.05035379$

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

fx = 0.04207769

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

af = 0.24098246

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

bmax = 600.00

hmax = 600.00

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.008$

bw = 250.00

effective stress from (A.35), $f_{f,e} = 720.2618$

fy = 0.04207769

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

af = 0.24098246

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

bmax = 600.00

hmax = 600.00

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.008$

bw = 250.00

effective stress from (A.35), $f_{f,e} = 720.2618$

R = 40.00

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.00$

fu,f = 840.00

Ef = 82000.00

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 $bi^2/6$ as defined at (A.2).

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

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

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

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

$fy_{we} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

$c = \text{confinement factor} = 1.06737$
 $y1 = 0.00140044$
 $sh1 = 0.0044814$
 $ft1 = 466.8167$
 $fy1 = 389.0139$
 $su1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.30$
 $su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs1 = fs = 389.0139$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00140044$
 $sh2 = 0.0044814$
 $ft2 = 466.8167$
 $fy2 = 389.0139$
 $su2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.30$
 $su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs2 = fs = 389.0139$
 with $Es2 = Es = 200000.00$
 $yv = 0.00140044$
 $shv = 0.0044814$
 $ftv = 466.8167$
 $fyv = 389.0139$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.30$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 389.0139$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0292549$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.06704247$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.07081015$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 12.00$
 $fcc (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.03435585$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.07873215$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.08315676$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.15879007$$

$$M_u = M_{Rc}(4.14) = 3.2075E+008$$

$$u = s_u(4.1) = 1.0927237E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$

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

$$V_{Col0} = 631439.816$$

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

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

= 1 (normal-weight concrete)

$$f_c' = 33.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$M_u = 90.31778$$

$$V_u = 0.14056349$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8933.736$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 593416.693$$

where:

$V_{s1} = 418882.372$ is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.20833333$$

$V_{s2} = 174534.321$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.50$$

$$V_f((11-3)-(11.4), ACI 440) = 365392.00$$

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

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

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

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

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

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

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.00$$

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

$$f_{fe}((11-5), ACI 440) = 328.00$$

$$E_f = 82000.00$$

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

$$\text{with } f_u = 0.009$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 457936.196$$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$

$$Vr2 = VCol \text{ ((10.3), ASCE 41-17)} = knl * VCol0$$

$$VCol0 = 544688.006$$

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

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

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

$$fc' = 33.00, \text{ but } fc^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$Mu = 330.5734$$

$$Vu = 0.14056349$$

$$d = 0.8 * h = 480.00$$

$$Nu = 8933.736$$

$$Ag = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } Vs = Vs1 + Vs2 = 593416.693$$

where:

Vs1 = 418882.372 is calculated for section web, with:

$$d = 480.00$$

$$Av = 157079.633$$

$$fy = 555.56$$

$$s = 100.00$$

Vs1 is multiplied by Col1 = 1.00

$$s/d = 0.20833333$$

Vs2 = 174534.321 is calculated for section flange, with:

$$d = 200.00$$

$$Av = 157079.633$$

$$fy = 555.56$$

$$s = 100.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.50$$

$$Vf \text{ ((11-3)-(11.4), ACI 440)} = 365392.00$$

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

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

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

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

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

$$\text{orientation 1: } \alpha = \alpha_1 + 90^\circ = 90.00$$

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

$$\text{total thickness per orientation, } tf1 = NL * t / \text{NoDir} = 1.00$$

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

$$ffe \text{ ((11-5), ACI 440)} = 328.00$$

$$Ef = 82000.00$$

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

$$\text{with } fu = 0.009$$

$$\text{From (11-11), ACI 440: } Vs + Vf \leq 457936.196$$

$$bw = 250.00$$

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rclcs

Constant Properties

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

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

Consequently:

$$\text{New material of Secondary Member: Concrete Strength, } fc = fcm = 33.00$$

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

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

#####

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 = 1.06737

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

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, $V_a = 0.14056349$

EDGE -B-

Shear Force, $V_b = -0.14056349$

BOTH EDGES

Axial Force, $F = -8933.736$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 4737.522$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1900.664$

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

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

Calculation of Shear Capacity ratio, $V_e/V_r = 0.73796687$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 6.0294E+008$

$M_{u1+} = 6.0294E+008$, 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

$M_{u1-} = 3.2075E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 6.0294E+008$

$M_{u2+} = 6.0294E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 3.2075E+008$, 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 u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.3372380E-005$$

$$Mu = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

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

$$f_x = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

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

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).

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

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

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

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 = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00267374
c = confinement factor = 1.06737

y1 = 0.00140044
sh1 = 0.0044814
ft1 = 466.8167
fy1 = 389.0139
su1 = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044
sh2 = 0.0044814
ft2 = 466.8167
fy2 = 389.0139
su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044
shv = 0.0044814
ftv = 466.8167
fyv = 389.0139
suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

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

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16061358

2 = Asl,com/(b*d)*(fs2/fc) = 0.07008593

v = Asl,mid/(b*d)*(fsv/fc) = 0.1696398

and confined core properties:

$b = 190.00$
 $d = 528.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22334125$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.097458$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23589266$
 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
 --->
 $su (4.8) = 0.31383738$
 $Mu = MRc (4.15) = 6.0294E+008$
 $u = su (4.1) = 1.3372380E-005$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Mu_1 -

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.0927237E-005$
 $Mu = 3.2075E+008$

 with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 42.00$
 $v = 0.00081005$
 $N = 8933.736$
 $f_c = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01247586$
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$
 where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04207769$
 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), $p_f = 2t_f/b_w = 0.008$
 $b_w = 250.00$
 effective stress from (A.35), $f_{f,e} = 720.2618$

 $f_y = 0.04207769$
 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), $p_f = 2t_f/b_w = 0.008$
 $b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{,f} = 0.015$

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

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."

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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).

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

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

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

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

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

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

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

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

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

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

with $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

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

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

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

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

For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

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

with $fs_2 = fs = 389.0139$

with $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$suv = 0.00512$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

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

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

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

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

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

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

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

with $fsv = fs = 389.0139$

with $Es_v = Es = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.0292549$

2 = $Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.06704247$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.07081015$

and confined core properties:

b = 540.00

d = 527.00

d' = 12.00

fcc (5A.2, TBDY) = 35.22334

cc (5A.5, TBDY) = 0.00267374

c = confinement factor = 1.06737

1 = $Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.03435585$

2 = $Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.07873215$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.08315676$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.15879007

$Mu = MRc$ (4.14) = 3.2075E+008

u = su (4.1) = 1.0927237E-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 = 1.3372380E-005

$Mu = 6.0294E+008$

with full section properties:

b = 250.00

d = 558.00

d' = 43.00

v = 0.00194064

N = 8933.736

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01247586$

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

From (5.4b), TBDY: $c_u = 0.01247586$

w_e ((5.4c), TBDY) = $a_{se} \cdot s_{h,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$

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)

$f_x = 0.04207769$

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), $p_f = 2t_f/b_w = 0.008$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$f_y = 0.04207769$

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), $p_f = 2t_f/b_w = 0.008$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$R = 40.00$

Effective FRP thickness, $t_f = N_L \cdot t \cdot \text{Cos}(b_1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{f} = 0.015$

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

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).

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

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

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

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

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00267374$

c = confinement factor = 1.06737

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

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

Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

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

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

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

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

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

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

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

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

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

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

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

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

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

lo/lou,min = lb/d = 0.30

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

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

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

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

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

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16061358

2 = Asl,com/(b*d)*(fs2/fc) = 0.07008593

v = Asl,mid/(b*d)*(fsv/fc) = 0.1696398

and confined core properties:

b = 190.00

d = 528.00

d' = 13.00

fcc (5A.2, TBDY) = 35.22334

cc (5A.5, TBDY) = 0.00267374

c = confinement factor = 1.06737

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22334125

2 = Asl,com/(b*d)*(fs2/fc) = 0.097458

v = Asl,mid/(b*d)*(fsv/fc) = 0.23589266

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) = 0.31383738

Mu = MRc (4.15) = 6.0294E+008

u = su (4.1) = 1.3372380E-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:

$$\mu = 1.0927237E-005$$

$$\mu_2 = 3.2075E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 42.00$$

$$v = 0.00081005$$

$$N = 8933.736$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

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

$$f_x = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

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

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).

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

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

earthquake detailing (90° closed stirrups)

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

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

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

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

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

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

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

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

$$s = 100.00$$

$$\text{fywe} = 694.45$$

$$\text{fce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: cc} = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y1 = 0.00140044$$

$$\text{sh1} = 0.0044814$$

$$\text{ft1} = 466.8167$$

$$\text{fy1} = 389.0139$$

$$\text{su1} = 0.00512$$

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

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

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

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

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

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

$$\text{with fs1} = \text{fs} = 389.0139$$

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

$$y2 = 0.00140044$$

$$\text{sh2} = 0.0044814$$

$$\text{ft2} = 466.8167$$

$$\text{fy2} = 389.0139$$

$$\text{su2} = 0.00512$$

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

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

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

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

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

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

$$\text{with fs2} = \text{fs} = 389.0139$$

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

$$yv = 0.00140044$$

$$\text{shv} = 0.0044814$$

$$\text{ftv} = 466.8167$$

$$\text{fyv} = 389.0139$$

$$\text{suv} = 0.00512$$

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

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

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

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

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

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

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

$$\text{with fsv} = \text{fs} = 389.0139$$

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

$$1 = \text{Asl,ten} / (\text{b} * \text{d}) * (\text{fs1} / \text{fc}) = 0.0292549$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.06704247$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$f_{cc} (5A.2, TBDY) = 35.22334$$

$$c_c (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07873215$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.15879007$$

$$M_u = M_{Rc} (4.14) = 3.2075E+008$$

$$u = s_u (4.1) = 1.0927237E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$

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

$$V_{Col0} = 631439.816$$

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

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

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

= 1 (normal-weight concrete)

$$f_c' = 33.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$M_u = 90.32855$$

$$V_u = 0.14056349$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8933.736$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 593416.693$$

where:

$V_{s1} = 174534.321$ is calculated for section web, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.50$$

$V_{s2} = 418882.372$ is calculated for section flange, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.20833333$$

$$V_f ((11-3)-(11.4), ACI 440) = 365392.00$$

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.00$

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

f_{fe} ((11-5), ACI 440) = 328.00

$E_f = 82000.00$

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

with $f_u = 0.009$

From (11-11), ACI 440: $V_s + V_f \leq 457936.196$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$

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

$V_{Col0} = 544688.006$

$k_{nl} = 1$ (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).

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

$f_c' = 33.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/d = 4.00$

$\mu_u = 330.5627$

$\nu_u = 0.14056349$

$d = 0.8 \cdot h = 480.00$

$N_u = 8933.736$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$

where:

$V_{s1} = 174534.321$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.50$

$V_{s2} = 418882.372$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.20833333$

V_f ((11-3)-(11.4), ACI 440) = 365392.00

$f = 0.95$, 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 $V_f(\theta)$, 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.00$

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

f_{fe} ((11-5), ACI 440) = 328.00

$E_f = 82000.00$

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

with $f_u = 0.009$

From (11-11), ACI 440: $V_s + V_f \leq 457936.196$

$b_w = 250.00$

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

At local axis: 2

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

At local axis: 2

Integration Section: (b)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

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, $M = -244487.076$

Shear Force, $V_2 = 5377.847$

Shear Force, $V_3 = -295.6742$

Axial Force, $F = -9837.676$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl} = 0.00$

-Compression: $A_{slc} = 4737.522$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1900.664$

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

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

Mean Diameter of Tension Reinforcement, $DbL = 17.25$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u,R = 1.0^*$ $u = 0.00190566$

$u = \gamma + \rho = 0.00190566$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00190566$ ((4.29), Biskinis Phd))
 $M_y = 3.7231E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 826.8799
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.3849E+013$
factor = 0.30
Ag = 237500.00
fc' = 33.00
N = 9837.676
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.4405701E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 311.2112$
d = 558.00
 $y = 0.37201073$
A = 0.03418733
B = 0.02205932
with pt = 0.01362483
pc = 0.00594538
pv = 0.01439052
N = 9837.676
b = 250.00
" = 0.07706093
 $y_{comp} = 1.0794145E-005$
with fc* (12.3, (ACI 440)) = 33.51939
fc = 33.00
fl = 0.77310341
b = bmax = 600.00
h = hmax = 600.00
Ag = 237500.00
g = pt + pc + pv = 0.03396073
rc = 40.00
Ae/Ac = 0.21429949
Effective FRP thickness, tf = NL*t*cos(b1) = 1.00
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.009
Ef = 82000.00
Ec = 26999.444
 $y = 0.37101492$
A = 0.03380294
B = 0.02183272
with Es = 200000.00

Calculation of ratio l_b / l_d

Inadequate Lap Length with $l_b / l_d = 0.30$

- Calculation of p -

From table 10-8: $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b / l_d \geq 1$
shear control ratio $V_y E / C_o I_o E = 0.73796687$
d = 558.00
s = 0.00
 $t = A_v / (b_w * s) + 2 * t_f / b_w * (f_f e / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_f e / f_s) = 0.00$

$A_v = 78.53982$, 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.

$N_{UD} = 9837.676$

$A_g = 237500.00$

$f_{cE} = 33.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.03396073$

$b = 250.00$

$d = 558.00$

$f_{cE} = 33.00$

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

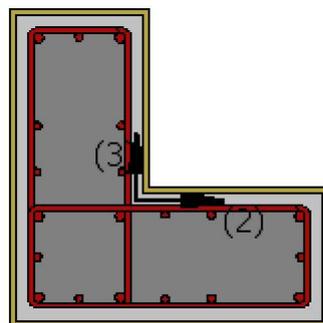
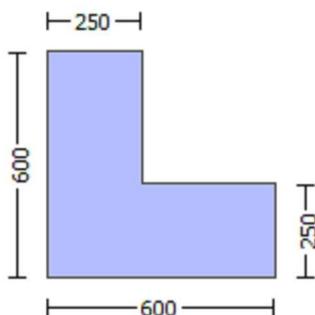
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rclcs

Constant Properties

Knowledge Factor, = 1.00

```

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$ 
New material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$ 
Concrete Elasticity,  $E_c = 26999.444$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE41-17).
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material: Steel Strength,  $f_s = f_{sm} = 555.56$ 
#####
Max Height,  $H_{max} = 600.00$ 
Min Height,  $H_{min} = 250.00$ 
Max Width,  $W_{max} = 600.00$ 
Min Width,  $W_{min} = 250.00$ 
Cover Thickness,  $c = 25.00$ 
Element Length,  $L = 3000.00$ 
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with  $l_o/l_{ou,min} = l_b/l_d = 0.30$ 
FRP Wrapping Data
Type: Carbon
Dry properties (design values)
Thickness,  $t = 1.00$ 
Tensile Strength,  $f_{fu} = 840.00$ 
Tensile Modulus,  $E_f = 82000.00$ 
Elongation,  $e_{fu} = 0.009$ 
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,  $M_a = -641478.12$ 
Shear Force,  $V_a = 295.6742$ 
EDGE -B-
Bending Moment,  $M_b = -244487.076$ 
Shear Force,  $V_b = -295.6742$ 
BOTH EDGES
Axial Force,  $F = -9837.676$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $A_{st} = 0.00$ 
-Compression:  $A_{sc} = 4737.522$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $A_{sl,ten} = 1900.664$ 
-Compression:  $A_{sl,com} = 829.3805$ 
-Middle:  $A_{sl,mid} = 2007.478$ 
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.25$ 
-----
-----

New component: From table 7-7, ASCE 41_17: Final Shear Capacity  $V_R = 1.0 * V_n = 550005.412$ 
 $V_n ((10.3), ASCE 41-17) = knl * V_{ColO} = 550005.412$ 
 $V_{Col} = 550005.412$ 
 $knl = 1.00$ 
displacement_ductility_demand = 1.7491344E-005
-----

```

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
fc' = 25.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
M/Vd = 2.00
Mu = 244487.076
Vu = 295.6742
d = 0.8*h = 480.00
Nu = 9837.676
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 534070.751
where:
Vs1 = 376991.118 is calculated for section web, with:
d = 480.00
Av = 157079.633
fy = 500.00
s = 100.00
Vs1 is multiplied by Col1 = 1.00
s/d = 0.20833333
Vs2 = 157079.633 is calculated for section flange, with:
d = 200.00
Av = 157079.633
fy = 500.00
s = 100.00
Vs2 is multiplied by Col2 = 1.00
s/d = 0.50
Vf ((11-3)-(11.4), ACI 440) = 365392.00
f = 0.95, for fully-wrapped sections
wf/sf = 1 (FRP strips adjacent to one another).
In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function Vf(θ), is implemented for every different fiber orientation ai,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = b1 + 90^\circ = 90.00$
Vf = Min(|Vf(45, 1)|, |Vf(-45, a1)|), with:
total thickness per orientation, tf1 = NL*t/NoDir = 1.00
dfv = d (figure 11.2, ACI 440) = 557.00
ffe ((11-5), ACI 440) = 328.00
Ef = 82000.00
fe = 0.004, from (11.6a), ACI 440
with fu = 0.009
From (11-11), ACI 440: Vs + Vf <= 398582.298
bw = 250.00

displacement ductility demand is calculated as δ / y

- Calculation of δ / y for END B -
for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 3.3332484E-008$
 $y = (My*Ls/3)/Eleff = 0.00190566$ ((4.29), Biskinis Phd)
My = 3.7231E+008
Ls = M/V (with $Ls > 0.1*L$ and $Ls < 2*L$) = 826.8799
From table 10.5, ASCE 41_17: Eleff = factor*Ec*Ig = 5.3849E+013
factor = 0.30
Ag = 237500.00
fc' = 33.00
N = 9837.676
Ec*Ig = 1.7950E+014

Calculation of Yielding Moment My

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.4405701\text{E-}006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/l_d)^{2/3}) = 311.2112$
 $d = 558.00$
 $y = 0.37201073$
 $A = 0.03418733$
 $B = 0.02205932$
with $p_t = 0.01362483$
 $p_c = 0.00594538$
 $p_v = 0.01439052$
 $N = 9837.676$
 $b = 250.00$
 $" = 0.07706093$
 $y_{\text{comp}} = 1.0794145\text{E-}005$
with f_c^* (12.3, (ACI 440)) = 33.51939
 $f_c = 33.00$
 $f_l = 0.77310341$
 $b = b_{\text{max}} = 600.00$
 $h = h_{\text{max}} = 600.00$
 $A_g = 237500.00$
 $g = p_t + p_c + p_v = 0.03396073$
 $r_c = 40.00$
 $A_e/A_c = 0.21429949$
Effective FRP thickness, $t_f = N L^* t \cdot \text{Cos}(b_1) = 1.00$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.009$
 $E_f = 82000.00$
 $E_c = 26999.444$
 $y = 0.37101492$
 $A = 0.03380294$
 $B = 0.02183272$
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: 3
Integration Section: (b)

Calculation No. 8

column C1, Floor 1

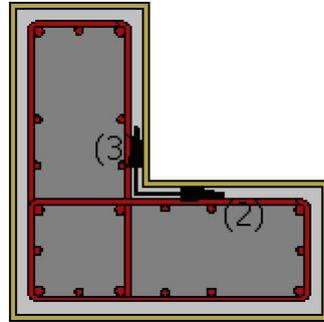
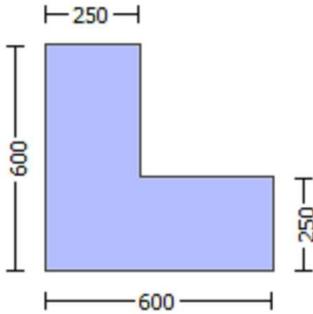
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

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 = 1.06737

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $ef_u = 0.009$

Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, Va = 0.14056349
EDGE -B-
Shear Force, Vb = -0.14056349
BOTH EDGES
Axial Force, F = -8933.736
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 4737.522
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1900.664
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 2007.478

Calculation of Shear Capacity ratio , $V_e/V_r = 0.73796687$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$
with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 6.0294E+008$
 $\mu_{1+} = 6.0294E+008$, 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
 $\mu_{1-} = 3.2075E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 6.0294E+008$
 $\mu_{2+} = 6.0294E+008$, 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
 $\mu_{2-} = 3.2075E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.3372380E-005$

$M_u = 6.0294E+008$

with full section properties:

$b = 250.00$

$d = 558.00$

$d' = 43.00$

$v = 0.00194064$

$N = 8933.736$

$f_c = 33.00$

$\alpha_{co} (5A.5, TBDY) = 0.002$

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01247586$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.01247586$

where $\mu_{we} (5.4c), TBDY) = \alpha_{se} * \text{sh}_{,\text{min}} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$

where $f = \alpha_f * \rho_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04207769$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.24098246$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $pf = 2t_f/b_w = 0.008$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$f_y = 0.04207769$

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), $pf = 2t_f/b_w = 0.008$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$R = 40.00$

Effective FRP thickness, $t_f = NL*t*\text{Cos}(b_1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}), 0) = 0.27151783$

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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su_1 = 0.4*su_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $su_{1,nominal} = 0.08$,

For calculation of $su_{1,nominal}$ 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 $f_{s1} = f_s = 389.0139$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00140044$
 $sh_2 = 0.0044814$
 $ft_2 = 466.8167$
 $fy_2 = 389.0139$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.30$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 389.0139$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00140044$
 $sh_v = 0.0044814$
 $ft_v = 466.8167$
 $fy_v = 389.0139$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsy_v = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsy_v = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 389.0139$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.16061358$
 $2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.07008593$
 $v = A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.1696398$

and confined core properties:

$b = 190.00$
 $d = 528.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.22334125$
 $2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.097458$
 $v = A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.23589266$

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
 --->
 $su (4.8) = 0.31383738$
 $Mu = MR_c (4.15) = 6.0294E+008$
 $u = su (4.1) = 1.3372380E-005$

 Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Mu_1 -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0927237E-005$$

$$\mu = 3.2075E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 42.00$$

$$v = 0.00081005$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$\alpha (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01247586$$

$$\phi_{cc} \text{ ((5.4c), TBDY) } = \alpha * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05035379$$

where $\phi_f = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 57233.333$$

$$b_{\text{max}} = 600.00$$

$$h_{\text{max}} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$\phi_{fy} = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 0.00$$

$$b_{\text{max}} = 600.00$$

$$h_{\text{max}} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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).

$$\text{psh}_{, \text{min}} = \text{Min}(\text{psh}_{,x}, \text{psh}_{,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $\text{psh}_{, \text{min}}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\text{psh}_{,x} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 237500.00$$

$$psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00482813$$

$$Lstir (\text{Length of stirrups along } X) = 1460.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 237500.00$$

$$s = 100.00$$

$$fywe = 694.45$$

$$fce = 33.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/d = 0.30$$

$$su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 389.0139$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 389.0139$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/d = 0.30$$

$$suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.0292549$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.06704247$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$fcc (5A.2, TBDY) = 35.22334$$

$$cc (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = \text{Asl,ten}/(b*d)*(fs1/fc) = 0.03435585$$

$$2 = \text{Asl,com}/(b*d)*(fs2/fc) = 0.07873215$$

$$v = \text{Asl,mid}/(b*d)*(fsv/fc) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.15879007$$

$$Mu = MRc (4.14) = 3.2075E+008$$

$$u = su (4.1) = 1.0927237E-005$$

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:

$$u = 1.3372380E-005$$

$$Mu = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$fc = 33.00$$

$$co (5A.5, TBDY) = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.01247586$$

$$w_e ((5.4c), TBDY) = ase * sh_{,min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.05035379$$

where $f = af * pf * ff_e/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff_e = 720.2618$$

$$fy = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff_e = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL * t * \text{Cos}(b1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.27151783$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 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).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00482813$$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00482813$$

$$Lstir \text{ (Length of stirrups along Y)} = 1460.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 237500.00$$

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00482813$$

$$Lstir \text{ (Length of stirrups along X)} = 1460.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$fywe = 694.45$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 389.0139$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2, ft2, fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 389.0139$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$f_{yv} = 389.0139$
 $s_{uv} = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,
 considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $e_{suv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered
 characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 389.0139$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16061358$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07008593$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1696398$

and confined core properties:

$b = 190.00$
 $d = 528.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22334125$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.097458$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23589266$

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

$s_u (4.8) = 0.31383738$

$M_u = MR_c (4.15) = 6.0294E+008$

$u = s_u (4.1) = 1.3372380E-005$

 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 u according to 4.1, Biskinis/Fardis 2013:

$u = 1.0927237E-005$

$M_u = 3.2075E+008$

 with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 42.00$

$v = 0.00081005$

$N = 8933.736$

$f_c = 33.00$

$co (5A.5, TBDY) = 0.002$

Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01247586$

where ((5.4c), TBDY) = $ase * sh_{,min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.05035379$

where $f = af * pf * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

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), $p_f = 2t_f/b_w = 0.008$

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 720.2618$

$$f_y = 0.04207769$$

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), $p_f = 2t_f/b_w = 0.008$

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 720.2618$

$$R = 40.00$$

Effective FRP thickness, $t_f = N_L * t * \cos(b_1) = 1.00$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$$

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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

From ((5.A5), TBDY), TBDY: $c_c = 0.00267374$

$$c = \text{confinement factor} = 1.06737$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 389.0139$

with $Es1 = Es = 200000.00$

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{min} = lb/lb_{min} = 0.30$

$su2 = 0.4 \cdot esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 389.0139$

with $Es2 = Es = 200000.00$

$yv = 0.00140044$

$shv = 0.0044814$

$ftv = 466.8167$

$fyv = 389.0139$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{min} = lb/ld = 0.30$

$suv = 0.4 \cdot esuv_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 389.0139$

with $Es = Es = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.0292549$

2 = $Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.06704247$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.07081015$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 12.00$

f_{cc} (5A.2, TBDY) = 35.22334

cc (5A.5, TBDY) = 0.00267374

c = confinement factor = 1.06737

1 = $Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.03435585$

2 = $Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.07873215$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.08315676$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.15879007

$Mu = MRc$ (4.14) = 3.2075E+008

$u = su$ (4.1) = 1.0927237E-005

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$
 $V_{r1} = V_{Co1} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Co1}$
 $V_{Co1} = 631439.816$
 $k_{nl} = 1$ (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).

 $\phi = 1$ (normal-weight concrete)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 90.31778$
 $V_u = 0.14056349$
 $d = 0.8 * h = 480.00$
 $N_u = 8933.736$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$
where:
 $V_{s1} = 418882.372$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.20833333$
 $V_{s2} = 174534.321$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 365392.00$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin^2 + \cos^2$ is replaced with $(\cot^2 + \csc^2) \sin^2 \alpha$ which is more a generalised expression,
where 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: $\alpha = 45^\circ$ and $\alpha = 90^\circ$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.00$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe} ((11-5), \text{ACI } 440) = 328.00$
 $E_f = 82000.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.009$
From (11-11), ACI 440: $V_s + V_f \leq 457936.196$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$
 $V_{r2} = V_{Co2} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Co2}$
 $V_{Co2} = 544688.006$
 $k_{nl} = 1$ (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).

 $\phi = 1$ (normal-weight concrete)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 330.5734$
 $V_u = 0.14056349$

$d = 0.8 \cdot h = 480.00$
 $Nu = 8933.736$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 593416.693$
 where:
 $Vs1 = 418882.372$ is calculated for section web, with:
 $d = 480.00$
 $Av = 157079.633$
 $fy = 555.56$
 $s = 100.00$
 $Vs1$ is multiplied by $Col1 = 1.00$
 $s/d = 0.20833333$
 $Vs2 = 174534.321$ is calculated for section flange, with:
 $d = 200.00$
 $Av = 157079.633$
 $fy = 555.56$
 $s = 100.00$
 $Vs2$ is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 Vf ((11-3)-(11.4), ACI 440) = 365392.00
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\alpha, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\alpha = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, a1)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.00$
 $dfv = d$ (figure 11.2, ACI 440) = 557.00
 ffe ((11-5), ACI 440) = 328.00
 $Ef = 82000.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.009$
 From (11-11), ACI 440: $Vs + Vf \leq 457936.196$
 $bw = 250.00$

 End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rclcs

Constant Properties

 Knowledge Factor, $\phi = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$
 #####
 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 = 1.06737
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{o,min} = 0.30$
FRP Wrapping Data
Type: Carbon
Dry properties (design values)
Thickness, $t = 1.00$
Tensile Strength, $f_{fu} = 840.00$
Tensile Modulus, $E_f = 82000.00$
Elongation, $e_{fu} = 0.009$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 0.14056349$
EDGE -B-
Shear Force, $V_b = -0.14056349$
BOTH EDGES
Axial Force, $F = -8933.736$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1900.664$
-Compression: $As_{c,com} = 829.3805$
-Middle: $As_{c,mid} = 2007.478$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.73796687$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 6.0294E+008$
 $Mu_{1+} = 6.0294E+008$, 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
 $Mu_{1-} = 3.2075E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 6.0294E+008$
 $Mu_{2+} = 6.0294E+008$, 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
 $Mu_{2-} = 3.2075E+008$, 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:
 $\phi_u = 1.3372380E-005$
 $M_u = 6.0294E+008$

with full section properties:

b = 250.00

d = 558.00

d' = 43.00

v = 0.00194064

N = 8933.736

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01247586$

we ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.05035379$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $fx = 0.04207769$

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), $pf = 2tf / bw = 0.008$

$bw = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

 $fy = 0.04207769$

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), $pf = 2tf / bw = 0.008$

$bw = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

R = 40.00

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

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).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00482813$

Expression ((5.4d), TBDY) for psh_{min} has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 psh_x ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

$fy_{we} = 694.45$

$f_{ce} = 33.00$

From ((5.A.5), TBDY), TBDY: $cc = 0.00267374$
 $c = \text{confinement factor} = 1.06737$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/d = 0.30$

$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 389.0139$

with $Es1 = Es = 200000.00$

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/lb,min = 0.30$

$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 389.0139$

with $Es2 = Es = 200000.00$

$yv = 0.00140044$

$shv = 0.0044814$

$ftv = 466.8167$

$fyv = 389.0139$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/d = 0.30$

$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 389.0139$

with $Esv = Es = 200000.00$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.16061358$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.07008593$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.1696398$

and confined core properties:

$b = 190.00$

$d = 528.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 35.22334$

$cc (5A.5, TBDY) = 0.00267374$

$c = \text{confinement factor} = 1.06737$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.22334125$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.097458$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.23589266$

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

--->

$$s_u(4.8) = 0.31383738$$

$$\mu = M R_c(4.15) = 6.0294E+008$$

$$u = s_u(4.1) = 1.3372380E-005$$

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

Calculation of μ_1 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0927237E-005$$

$$\mu = 3.2075E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 42.00$$

$$v = 0.00081005$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$\alpha(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_s) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \mu_c = 0.01247586$$

$$\mu_s \text{ ((5.4c), TB DY) = } \alpha * \text{sh_min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

where $f = \alpha * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TB DY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 57233.333$$

$$b_{\text{max}} = 600.00$$

$$h_{\text{max}} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TB DY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 0.00$$

$$b_{\text{max}} = 600.00$$

$$h_{\text{max}} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.00$$

$$f_u, f = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{conf,max} = 169100.00$ 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

 $s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

$c = \text{confinement factor} = 1.06737$

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su_1 = 0.4 * esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$

$su_2 = 0.4 * esu_{2,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 389.0139$

with $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.0292549$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.06704247$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$fcc (5A.2, TBDY) = 35.22334$$

$$cc (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.03435585$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.07873215$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.15879007$$

$$Mu = MRc (4.14) = 3.2075E+008$$

$$u = su (4.1) = 1.0927237E-005$$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of $Mu2+$

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.3372380E-005$$

$$Mu = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$fc = 33.00$$

$$co (5A.5, TBDY) = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.01247586$$

$$we ((5.4c), TBDY) = ase * sh,min * fywe / fce + \text{Min}(fx, fy) = 0.05035379$$

where $f = af * pf * ffe / fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$$af = 0.24098246$$

$$\text{with Unconfined area} = ((bmax-2R)^2 + (hmax-2R)^2) / 3 = 57233.333$$

$$bmax = 600.00$$

$$hmax = 600.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008$$

$$bw = 250.00$$

effective stress from (A.35), $f_{f,e} = 720.2618$

$f_y = 0.04207769$

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), $p_f = 2t_f/b_w = 0.008$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$R = 40.00$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) \cdot (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$

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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} \cdot A_{\text{stir}} / (A_{\text{sec}} \cdot s) = 0.00482813$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} \cdot A_{\text{stir}} / (A_{\text{sec}} \cdot s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su_1 = 0.4 \cdot esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$$f_y2 = 389.0139$$

$$s_u2 = 0.00512$$

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

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,

For calculation of $e_{su2,nominal}$ and y_2, sh_2, ft_2, f_y2 , it is considered
characteristic value $f_{sy2} = f_s2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_y1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 389.0139$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$f_{y_v} = 389.0139$$

$$s_{u_v} = 0.00512$$

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

$$l_o/l_{o,u,min} = l_b/l_d = 0.30$$

$$s_{u_v} = 0.4 * e_{su_v,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su_v,nominal} = 0.08$,

considering characteristic value $f_{sy_v} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{su_v,nominal}$ and y_v, sh_v, ft_v, f_{y_v} , it is considered
characteristic value $f_{sv} = f_s/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_y1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 389.0139$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.16061358$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07008593$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.1696398$$

and confined core properties:

$$b = 190.00$$

$$d = 528.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 35.22334$$

$$c_c (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.22334125$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.097458$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.23589266$$

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

--->

$$s_u (4.8) = 0.31383738$$

$$\mu_u = M_{Rc} (4.15) = 6.0294E+008$$

$$u = s_u (4.1) = 1.3372380E-005$$

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 u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0927237E-005$$

Mu = 3.2075E+008

with full section properties:

b = 600.00

d = 557.00

d' = 42.00

v = 0.00081005

N = 8933.736

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01247586$

we ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.05035379$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$fx = 0.04207769$

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), $pf = 2tf / bw = 0.008$

$bw = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$fy = 0.04207769$

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), $pf = 2tf / bw = 0.008$

$bw = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

R = 40.00

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$

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 $bi^2/6$ as defined at (A.2).

$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $p_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$

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

$s = 100.00$
 $fy_{we} = 694.45$
 $f_{ce} = 33.00$
 From ((5.A.5), TBDY), TBDY: $cc = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $y_1 = 0.00140044$
 $sh_1 = 0.0044814$
 $ft_1 = 466.8167$
 $fy_1 = 389.0139$
 $su_1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.30$
 $su_1 = 0.4 * esu_{1_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{1_nominal} = 0.08$,
 For calculation of $esu_{1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 389.0139$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.00140044$
 $sh_2 = 0.0044814$
 $ft_2 = 466.8167$
 $fy_2 = 389.0139$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 0.30$
 $su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2_nominal} = 0.08$,
 For calculation of $esu_{2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 389.0139$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00140044$
 $sh_v = 0.0044814$
 $ft_v = 466.8167$
 $fy_v = 389.0139$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 0.30$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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 $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 389.0139$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten}/(b * d) * (fs_1 / fc) = 0.0292549$
 $2 = Asl, \text{com}/(b * d) * (fs_2 / fc) = 0.06704247$
 $v = Asl, \text{mid}/(b * d) * (fsv / fc) = 0.07081015$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = Asl, \text{ten}/(b * d) * (fs_1 / fc) = 0.03435585$
 $2 = Asl, \text{com}/(b * d) * (fs_2 / fc) = 0.07873215$
 $v = Asl, \text{mid}/(b * d) * (fsv / fc) = 0.08315676$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->
 $\mu_{su} (4.9) = 0.15879007$
 $\mu_{MRc} (4.14) = 3.2075E+008$
 $u = \mu_{su} (4.1) = 1.0927237E-005$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$
 $V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$
 $V_{Col0} = 631439.816$
 $k_{nl} = 1$ (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).

 $\beta = 1$ (normal-weight concrete)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_{su} = 90.32855$
 $\mu_{Vu} = 0.14056349$
 $d = 0.8 * h = 480.00$
 $N_u = 8933.736$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$
where:
 $V_{s1} = 174534.321$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 418882.372$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 $V_f ((11-3)-(11.4), ACI 440) = 365392.00$
 $f = 0.95$, 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 $V_f(\alpha)$, is implemented for every different fiber orientation α_i ,
as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\alpha = 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$, with:
total thickness per orientation, $t_f = N_L * t / N_{Dir} = 1.00$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe} ((11-5), ACI 440) = 328.00$
 $E_f = 82000.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.009$
From (11-11), ACI 440: $V_s + V_f \leq 457936.196$

bw = 250.00

Calculation of Shear Strength at edge 2, Vr2 = 544688.006
Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 544688.006
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' = 33.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 330.5627
Vu = 0.14056349
d = 0.8*h = 480.00
Nu = 8933.736
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 593416.693

where:

Vs1 = 174534.321 is calculated for section web, with:

d = 200.00
Av = 157079.633
fy = 555.56
s = 100.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.50

Vs2 = 418882.372 is calculated for section flange, with:

d = 480.00
Av = 157079.633
fy = 555.56
s = 100.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.20833333

Vf ((11-3)-(11.4), ACI 440) = 365392.00

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot)\sin\alpha$ which is more a generalised expression,
where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(α), is implemented for every different fiber orientation ai,
as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, α)|, |Vf(-45, α)|), with:

total thickness per orientation, tf1 = NL*t/NoDir = 1.00

dfv = d (figure 11.2, ACI 440) = 557.00

ffe ((11-5), ACI 440) = 328.00

Ef = 82000.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.009

From (11-11), ACI 440: Vs + Vf <= 457936.196

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\phi = 1.00$
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 600.00$
Min Height, $H_{min} = 250.00$
Max Width, $W_{max} = 600.00$
Min Width, $W_{min} = 250.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_b/l_d = 0.30$
FRP Wrapping Data
Type: Carbon
Dry properties (design values)
Thickness, $t = 1.00$
Tensile Strength, $f_{fu} = 840.00$
Tensile Modulus, $E_f = 82000.00$
Elongation, $e_{fu} = 0.009$
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, $M = 287980.756$
Shear Force, $V_2 = 5377.847$
Shear Force, $V_3 = -295.6742$
Axial Force, $F = -9837.676$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl} = 0.00$
-Compression: $A_{slc} = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1900.664$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 2007.478$
Mean Diameter of Tension Reinforcement, $D_bL = 17.25$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^* u = 0.00069139$
 $u = y + p = 0.00069139$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00069139$ ((4.29), Biskinis Phd)
 $M_y = 3.7231E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.3849E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 33.00$
 $N = 9837.676$
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.4405701\text{E-}006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 311.2112$
 $d = 558.00$
 $y = 0.37201073$
 $A = 0.03418733$
 $B = 0.02205932$
with $pt = 0.01362483$
 $pc = 0.00594538$
 $pv = 0.01439052$
 $N = 9837.676$
 $b = 250.00$
 $\rho = 0.07706093$
 $y_{\text{comp}} = 1.0794145\text{E-}005$
with $f_c^* (12.3, (ACI 440)) = 33.51939$
 $f_l = 33.00$
 $fl = 0.77310341$
 $b = b_{\text{max}} = 600.00$
 $h = h_{\text{max}} = 600.00$
 $Ag = 237500.00$
 $g = pt + pc + pv = 0.03396073$
 $rc = 40.00$
 $Ae/Ac = 0.21429949$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b1) = 1.00$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.009$
 $E_f = 82000.00$
 $E_c = 26999.444$
 $y = 0.37101492$
 $A = 0.03380294$
 $B = 0.02183272$
with $E_s = 200000.00$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

- Calculation of ρ_p -

From table 10-8: $\rho_p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$
shear control ratio $V_y E / V_{CoI} E = 0.73796687$

$d = 558.00$

$s = 0.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = A_v \cdot L_{\text{stir}} / (A_g \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{\text{stir}} = 1460.00$, is the total length of all stirrups parallel to loading (shear) direction

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$NUD = 9837.676$

$Ag = 237500.00$

$f_c E = 33.00$

$f_y E = f_{yE} = 0.00$

$\rho_l = \text{Area}_{\text{Tot_Long_Rein}} / (b \cdot d) = 0.03396073$

$b = 250.00$

$d = 558.00$

$f_{cE} = 33.00$

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

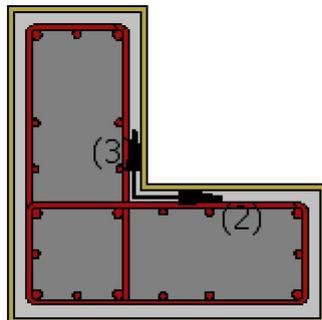
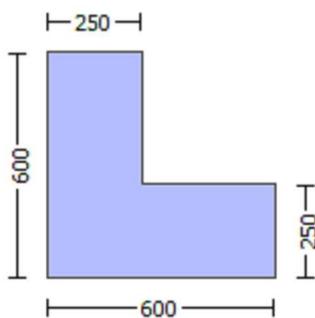
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rdc

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of 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).

New material: Concrete Strength, $f_c = f_{cm} = 33.00$

New material: Steel Strength, $f_s = f_{sm} = 555.56$

Max Height, $H_{max} = 600.00$
Min Height, $H_{min} = 250.00$
Max Width, $W_{max} = 600.00$
Min Width, $W_{min} = 250.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{o,min} = l_b/l_d = 0.30$
FRP Wrapping Data
Type: Carbon
Dry properties (design values)
Thickness, $t = 1.00$
Tensile Strength, $f_{fu} = 840.00$
Tensile Modulus, $E_f = 82000.00$
Elongation, $e_{fu} = 0.009$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -1.0439E+007$
Shear Force, $V_a = -3417.76$
EDGE -B-
Bending Moment, $M_b = 183142.393$
Shear Force, $V_b = 3417.76$
BOTH EDGES
Axial Force, $F = -9508.222$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1900.664$
-Compression: $As_{c,com} = 829.3805$
-Middle: $As_{mid} = 2007.478$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.25$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0*V_n = 474261.328$
 V_n ((10.3), ASCE 41-17) = $k_nl*V_{CoI0} = 474261.328$
 $V_{CoI} = 474261.328$
 $k_nl = 1.00$
displacement_ductility_demand = 0.00960865

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)
 $f_c' = 25.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 1.0439E+007$
 $V_u = 3417.76$
 $d = 0.8*h = 480.00$
 $N_u = 9508.222$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 534070.751$

where:

Vs1 = 157079.633 is calculated for section web, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 500.00$$

$$s = 100.00$$

Vs1 is multiplied by Col1 = 1.00

$$s/d = 0.50$$

Vs2 = 376991.118 is calculated for section flange, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 500.00$$

$$s = 100.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.20833333$$

Vf ((11-3)-(11.4), ACI 440) = 365392.00

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 α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, α)|, |Vf(-45, α)|), with:

total thickness per orientation, $t_{f1} = NL*t/NoDir = 1.00$

dfv = d (figure 11.2, ACI 440) = 557.00

ffe ((11-5), ACI 440) = 328.00

$$E_f = 82000.00$$

fe = 0.004, from (11.6a), ACI 440

with fu = 0.009

From (11-11), ACI 440: Vs + Vf <= 398582.298

$$bw = 250.00$$

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 $\theta = 6.7624388E-005$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00703787 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 3.7224E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 3054.316$$

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 5.3849E+013$

$$\text{factor} = 0.30$$

$$A_g = 237500.00$$

$$f_c' = 33.00$$

$$N = 9508.222$$

$$E_c * I_g = 1.7950E+014$$

Calculation of Yielding Moment My

Calculation of δ / y and My according to Annex 7 -

$$y = \text{Min}(y_{ten}, y_{com})$$

$$y_{ten} = 4.4401709E-006$$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$

$$d = 558.00$$

$$y = 0.37195426$$

$$A = 0.03417974$$

$$B = 0.02205173$$

with pt = 0.01362483

$$pc = 0.00594538$$

$$pv = 0.01439052$$

N = 9508.222
b = 250.00
" = 0.07706093
y_comp = 1.0794825E-005
with f_c^* (12.3, (ACI 440)) = 33.51939
f_c = 33.00
f_l = 0.77310341
b = b_{max} = 600.00
h = h_{max} = 600.00
A_g = 237500.00
g = p_t + p_c + p_v = 0.03396073
r_c = 40.00
A_e/A_c = 0.21429949
Effective FRP thickness, t_f = NL*t*cos(b₁) = 1.00
effective strain from (12.5) and (12.12), e_{fe} = 0.004
f_u = 0.009
E_f = 82000.00
E_c = 26999.444
y = 0.37099155
A = 0.03380823
B = 0.02183272
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: (a)

Calculation No. 10

column C1, Floor 1

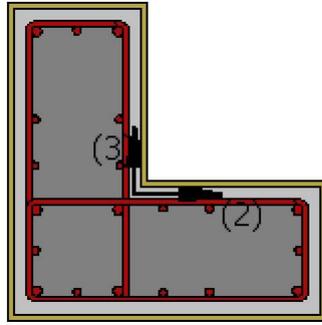
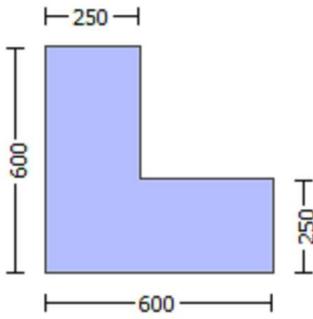
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (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, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$

 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

 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 = 1.06737
 Element Length, $L = 3000.00$

Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Dry properties (design values)
 Thickness, $t = 1.00$
 Tensile Strength, $f_{fu} = 840.00$
 Tensile Modulus, $E_f = 82000.00$
 Elongation, $e_{fu} = 0.009$
 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, $V_a = 0.14056349$
 EDGE -B-
 Shear Force, $V_b = -0.14056349$

BOTH EDGES

Axial Force, $F = -8933.736$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 4737.522$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{,ten} = 1900.664$

-Compression: $As_{,com} = 829.3805$

-Middle: $As_{,mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.73796687$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 6.0294E+008$

$Mu_{1+} = 6.0294E+008$, 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

$Mu_{1-} = 3.2075E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 6.0294E+008$

$Mu_{2+} = 6.0294E+008$, 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

$Mu_{2-} = 3.2075E+008$, 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:

$\phi_u = 1.3372380E-005$

$M_u = 6.0294E+008$

with full section properties:

$b = 250.00$

$d = 558.00$

$d' = 43.00$

$v = 0.00194064$

$N = 8933.736$

$f_c = 33.00$

$\omega (5A.5, \text{TBDY}) = 0.002$

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01247586$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01247586$

where $\phi_u (5.4c, \text{TBDY}) = a_s e^* \phi_{u, \text{min}} * f_{y, \text{we}} / f_{c, \text{e}} + \text{Min}(\phi_x, \phi_y) = 0.05035379$

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)

$\phi_x = 0.04207769$

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), $\phi_f = 2t_f / b_w = 0.008$

$b_w = 250.00$

effective stress from (A.35), $f_{f, \text{e}} = 720.2618$

$\phi_y = 0.04207769$

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), $pf = 2t_f/bw = 0.008$
 $bw = 250.00$
effective stress from (A.35), $ff_e = 720.2618$

$R = 40.00$
Effective FRP thickness, $t_f = NL*t*Cos(b1) = 1.00$
 $f_{u,f} = 840.00$
 $E_f = 82000.00$
 $u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$
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).

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $psh_{,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$psh_{,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$s = 100.00$
 $f_{ywe} = 694.45$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$
 $c = \text{confinement factor} = 1.06737$

$y1 = 0.00140044$
 $sh1 = 0.0044814$
 $ft1 = 466.8167$
 $fy1 = 389.0139$
 $su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $fs1 = fs = 389.0139$

with $Es1 = Es = 200000.00$

$y2 = 0.00140044$
 $sh2 = 0.0044814$
 $ft2 = 466.8167$
 $fy2 = 389.0139$
 $su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$

$su2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $es_{u2_nominal}$ and y_2 , sh_2, ft_2, fy_2 , it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 389.0139$

with $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.30$

$suv = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY

For calculation of $es_{uv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.

y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_v = fs = 389.0139$

with $Es_v = Es = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/fc) = 0.16061358$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/fc) = 0.07008593$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/fc) = 0.1696398$

and confined core properties:

$b = 190.00$

$d = 528.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 35.22334$

$cc (5A.5, TBDY) = 0.00267374$

$c = \text{confinement factor} = 1.06737$

1 = $As_{l,ten}/(b \cdot d) \cdot (fs_1/fc) = 0.22334125$

2 = $As_{l,com}/(b \cdot d) \cdot (fs_2/fc) = 0.097458$

$v = As_{l,mid}/(b \cdot d) \cdot (fs_v/fc) = 0.23589266$

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

--->

$su (4.8) = 0.31383738$

$Mu = MRc (4.15) = 6.0294E+008$

$u = su (4.1) = 1.3372380E-005$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu_1 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 1.0927237E-005$

$Mu = 3.2075E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 42.00$

$v = 0.00081005$

$N = 8933.736$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$\text{we ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$$

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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$f_{y1} = 389.0139$
 $s_{u1} = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30$
 $s_{u1} = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,
 For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, f_{y1} , it is considered
 characteristic value $f_{s1} = f_s/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s1} = f_s = 389.0139$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00140044$
 $sh_2 = 0.0044814$
 $ft_2 = 466.8167$
 $f_{y2} = 389.0139$
 $s_{u2} = 0.00512$
 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
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$
 $s_{u2} = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,
 For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, f_{y2} , it is considered
 characteristic value $f_{s2} = f_s/1.2$, from table 5.1, TBDY.
 y_2, sh_2, ft_2, f_{y2} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 389.0139$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00140044$
 $sh_v = 0.0044814$
 $ft_v = 466.8167$
 $f_{yv} = 389.0139$
 $s_{uv} = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,
 considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $e_{suv_nominal}$ and y_v, sh_v, ft_v, f_{yv} , it is considered
 characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 389.0139$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0292549$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.06704247$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07081015$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07873215$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08315676$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $s_u (4.9) = 0.15879007$
 $M_u = M_{Rc} (4.14) = 3.2075E+008$
 $u = s_u (4.1) = 1.0927237E-005$

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:

$$\mu = 1.3372380E-005$$

$$\mu_{2+} = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_{cu}^* = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.01247586$$

$$\mu_{cc} \text{ (5.4c), TBDY} = a_{se} * s_{h,min} * f_{y,we} / f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

where $f_x = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$$

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."

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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).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00482813$$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00482813$$

$$Lstir \text{ (Length of stirrups along Y)} = 1460.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 237500.00$$

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00482813$$

$$Lstir \text{ (Length of stirrups along X)} = 1460.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$fywe = 694.45$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lo,min = lb/ld = 0.30$$

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs/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.

$$\text{with } fs1 = fs = 389.0139$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lo,min = lb/lb,min = 0.30$$

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs/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.

$$\text{with } fs2 = fs = 389.0139$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lo,min = lb/ld = 0.30$$

$$suv = 0.4 * esuv_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 389.0139$$

with $E_{sv} = E_s = 200000.00$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16061358$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07008593$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1696398$$

and confined core properties:

$$b = 190.00$$

$$d = 528.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 35.22334$$

$$c_c (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22334125$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.097458$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23589266$$

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

--->

$$s_u (4.8) = 0.31383738$$

$$\mu_u = M_{Rc} (4.15) = 6.0294E+008$$

$$u = s_u (4.1) = 1.3372380E-005$$

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

Calculation of μ_u -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0927237E-005$$

$$\mu_u = 3.2075E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 42.00$$

$$v = 0.00081005$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max}-2R)^2 + (h_{\max}-2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL*t*\text{Cos}(b1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

$$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$$

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)

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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).

$$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $psh_{,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_{,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$psh_{,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$su1 = 0.4 * esu1_{\text{nominal}} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{\text{nominal}} = 0.08,$$

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.

$$\text{with } fs1 = fs = 389.0139$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{su2_nominal} ((5.5), TBDY) = 0.032$$

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_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.

$$\text{with } f_{s2} = f_s = 389.0139$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$s_{uv} = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.30$$

$$s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } f_{sv} = f_s = 389.0139$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0292549$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.06704247$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$f_{cc} (5A.2, TBDY) = 35.22334$$

$$c_c (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07873215$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.15879007$$

$$\mu_u = M_{Rc} (4.14) = 3.2075E+008$$

$$u = s_u (4.1) = 1.0927237E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$

$$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} * V_{Co10}$$

$$V_{Co10} = 631439.816$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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).

$$= 1 \text{ (normal-weight concrete)}$$

$$f_c' = 33.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$M/Vd = 2.00$
 $\mu_u = 90.31778$
 $V_u = 0.14056349$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8933.736$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$
 where:
 $V_{s1} = 418882.372$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.20833333$
 $V_{s2} = 174534.321$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 $V_f ((11-3)-(11.4), ACI 440) = 365392.00$
 $f = 0.95$, 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 $V_f(\alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\alpha = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / N_{oDir} = 1.00$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe} ((11-5), ACI 440) = 328.00$
 $E_f = 82000.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.009$
 From (11-11), ACI 440: $V_s + V_f \leq 457936.196$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 544688.006$
 $k_{nl} = 1$ (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)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 330.5734$
 $V_u = 0.14056349$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8933.736$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$
 where:
 $V_{s1} = 418882.372$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.20833333$
 $V_{s2} = 174534.321$ is calculated for section flange, with:

d = 200.00
 Av = 157079.633
 fy = 555.56
 s = 100.00
 Vs2 is multiplied by Col2 = 1.00
 s/d = 0.50
 Vf ((11-3)-(11.4), ACI 440) = 365392.00
 f = 0.95, for fully-wrapped sections
 wf/sf = 1 (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function Vf(θ), is implemented for every different fiber orientation ai,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 Vf = Min(|Vf(45, θ_1)|, |Vf(-45, θ_1)|), with:
 total thickness per orientation, tf1 = NL*t/NoDir = 1.00
 dfv = d (figure 11.2, ACI 440) = 557.00
 ffe ((11-5), ACI 440) = 328.00
 Ef = 82000.00
 fe = 0.004, from (11.6a), ACI 440
 with fu = 0.009
 From (11-11), ACI 440: Vs + Vf <= 457936.196
 bw = 250.00

 End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rclcs

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 New material of Secondary Member: Concrete Strength, fc = fcm = 33.00
 New material of Secondary Member: Steel Strength, fs = fsm = 555.56
 Concrete Elasticity, Ec = 26999.444
 Steel Elasticity, Es = 200000.00
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 New material: Steel Strength, fs = 1.25*fsm = 694.45
 #####
 Max Height, Hmax = 600.00
 Min Height, Hmin = 250.00
 Max Width, Wmax = 600.00
 Min Width, Wmin = 250.00
 Cover Thickness, c = 25.00
 Mean Confinement Factor overall section = 1.06737
 Element Length, L = 3000.00
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with lo/lou,min = 0.30
 FRP Wrapping Data
 Type: Carbon
 Dry properties (design values)
 Thickness, t = 1.00

Tensile Strength, $f_{fu} = 840.00$
Tensile Modulus, $E_f = 82000.00$
Elongation, $e_{fu} = 0.009$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 0.14056349$
EDGE -B-
Shear Force, $V_b = -0.14056349$
BOTH EDGES
Axial Force, $F = -8933.736$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_{lt} = 0.00$
-Compression: $As_{lc} = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 1900.664$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.73796687$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$
with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 6.0294E+008$
 $Mu_{1+} = 6.0294E+008$, 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
 $Mu_{1-} = 3.2075E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 6.0294E+008$
 $Mu_{2+} = 6.0294E+008$, 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
 $Mu_{2-} = 3.2075E+008$, 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:
 $\phi_u = 1.3372380E-005$
 $Mu = 6.0294E+008$

with full section properties:

$b = 250.00$
 $d = 558.00$
 $d' = 43.00$
 $v = 0.00194064$
 $N = 8933.736$
 $f_c = 33.00$
 ϕ_o (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_o) = 0.01247586$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.01247586$
 ϕ_{we} ((5.4c), TBDY) = $ase * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05035379$
where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

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), $p_f = 2t_f/b_w = 0.008$

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 720.2618$

$$f_y = 0.04207769$$

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), $p_f = 2t_f/b_w = 0.008$

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 720.2618$

$$R = 40.00$$

Effective FRP thickness, $t_f = N_L * t * \cos(b_1) = 1.00$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$$

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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

From ((5.A5), TBDY), TBDY: $c_c = 0.00267374$

$$c = \text{confinement factor} = 1.06737$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 389.0139$

with $Es1 = Es = 200000.00$

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou, min = lb/lb, min = 0.30$

$su2 = 0.4 \cdot esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 389.0139$

with $Es2 = Es = 200000.00$

$yv = 0.00140044$

$shv = 0.0044814$

$ftv = 466.8167$

$fyv = 389.0139$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou, min = lb/ld = 0.30$

$suv = 0.4 \cdot esuv_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 389.0139$

with $Es = Es = 200000.00$

1 = $Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.16061358$

2 = $Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.07008593$

v = $Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.1696398$

and confined core properties:

$b = 190.00$

$d = 528.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 35.22334

cc (5A.5, TBDY) = 0.00267374

c = confinement factor = 1.06737

1 = $Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.22334125$

2 = $Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.097458$

v = $Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.23589266$

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) = 0.31383738

$Mu = MRc$ (4.15) = 6.0294E+008

$u = su$ (4.1) = 1.3372380E-005

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.0927237E-005$$

$$Mu = 3.2075E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 42.00$$

$$v = 0.00081005$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.27151783$$

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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

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 = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00267374
c = confinement factor = 1.06737

y1 = 0.00140044
sh1 = 0.0044814
ft1 = 466.8167
fy1 = 389.0139
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044
sh2 = 0.0044814
ft2 = 466.8167
fy2 = 389.0139
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044
shv = 0.0044814
ftv = 466.8167
fyv = 389.0139
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0292549

2 = Asl,com/(b*d)*(fs2/fc) = 0.06704247

v = Asl,mid/(b*d)*(fsv/fc) = 0.07081015

and confined core properties:

b = 540.00

$d = 527.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07873215$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08315676$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.15879007$
 $Mu = MRc (4.14) = 3.2075E+008$
 $u = su (4.1) = 1.0927237E-005$

 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:
 $u = 1.3372380E-005$
 $Mu = 6.0294E+008$

with full section properties:

$b = 250.00$
 $d = 558.00$
 $d' = 43.00$
 $v = 0.00194064$
 $N = 8933.736$
 $f_c = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01247586$
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$
 where $f = a_{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04207769$
 Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$
 $a_f = 0.24098246$
 with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$
 $b_{max} = 600.00$
 $h_{max} = 600.00$
 From EC8 A.4.4.3(6), $pf = 2t_f/b_w = 0.008$
 $b_w = 250.00$
 effective stress from (A.35), $f_{f,e} = 720.2618$

 $f_y = 0.04207769$
 Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$
 $a_f = 0.24098246$
 with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$
 $b_{max} = 600.00$
 $h_{max} = 600.00$
 From EC8 A.4.4.3(6), $pf = 2t_f/b_w = 0.008$
 $b_w = 250.00$
 effective stress from (A.35), $f_{f,e} = 720.2618$

 $R = 40.00$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

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).

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $psh_{,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00482813$

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

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su_1 = 0.4 \cdot esu_{1,nominal}$ ((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 $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$su_2 = 0.4 \cdot esu_{2,nominal}$ ((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 $fs_2 = fs = 389.0139$

with $Es_2 = Es = 200000.00$

$y_v = 0.00140044$
 $sh_v = 0.0044814$
 $ft_v = 466.8167$
 $fy_v = 389.0139$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = fs = 389.0139$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.16061358$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.07008593$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.1696398$

and confined core properties:

$b = 190.00$
 $d = 528.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.22334125$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.097458$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.23589266$

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
 --->

$su (4.8) = 0.31383738$
 $Mu = MRc (4.15) = 6.0294E+008$
 $u = su (4.1) = 1.3372380E-005$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu_2

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 1.0927237E-005$
 $Mu = 3.2075E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 42.00$
 $v = 0.00081005$
 $N = 8933.736$
 $fc = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01247586$

w_e ((5.4c), TBDY) = $a_{se} \cdot s_{h,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$
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)

$f_x = 0.04207769$

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), $p_f = 2t_f/b_w = 0.008$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$f_y = 0.04207769$

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), $p_f = 2t_f/b_w = 0.008$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$R = 40.00$

Effective FRP thickness, $t_f = N_L \cdot t \cdot \text{Cos}(b_1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{f} = 0.015$

$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) \cdot (A_{conf,min}/A_{conf,max}), 0) = 0.27151783$

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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir}/(A_{sec} \cdot s) = 0.00482813$

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) = $L_{stir} \cdot A_{stir}/(A_{sec} \cdot s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$$l_o/l_{o,min} = l_b/l_d = 0.30$$

$$s_u1 = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } f_{s1} = f_s = 389.0139$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$s_u2 = 0.00512$$

using (30) in Bisikinis/Fardis (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.

$$\text{with } f_{s2} = f_s = 389.0139$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$s_uv = 0.00512$$

using (30) in Bisikinis/Fardis (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.

$$\text{with } f_{sv} = f_s = 389.0139$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.0292549$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.06704247$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$f_{cc} (5A.2, TBDY) = 35.22334$$

$$c_c (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.03435585$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07873215$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.15879007$$

$$\mu_u = M_{Rc} (4.14) = 3.2075E+008$$

$$u = s_u (4.1) = 1.0927237E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$
 $V_{r1} = V_{Co1} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Co10}$
 $V_{Co10} = 631439.816$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

$\rho = 1$ (normal-weight concrete)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 90.32855$
 $V_u = 0.14056349$
 $d = 0.8 * h = 480.00$
 $N_u = 8933.736$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$
where:
 $V_{s1} = 174534.321$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 418882.372$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 365392.00$
 $f = 0.95$, 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: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:
total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.00$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe} ((11-5), \text{ACI } 440) = 328.00$
 $E_f = 82000.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.009$
From (11-11), ACI 440: $V_s + V_f \leq 457936.196$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$
 $V_{r2} = V_{Co2} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Co10}$
 $V_{Co10} = 544688.006$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

$\rho = 1$ (normal-weight concrete)
 $f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$
 $\mu_u = 330.5627$
 $V_u = 0.14056349$
 $d = 0.8 \cdot h = 480.00$
 $Nu = 8933.736$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$
 where:
 $V_{s1} = 174534.321$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 418882.372$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 V_f ((11-3)-(11.4), ACI 440) = 365392.00
 $f = 0.95$, 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: $\theta = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / NoDir = 1.00$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 f_{fe} ((11-5), ACI 440) = 328.00
 $E_f = 82000.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.009$
 From (11-11), ACI 440: $V_s + V_f \leq 457936.196$
 $b_w = 250.00$

 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: rclcs

Constant Properties

Knowledge Factor, $\phi = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 Max Height, $H_{max} = 600.00$
 Min Height, $H_{min} = 250.00$
 Max Width, $W_{max} = 600.00$
 Min Width, $W_{min} = 250.00$
 Cover Thickness, $c = 25.00$

Element Length, L = 3000.00
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_b/l_d = 0.30$
FRP Wrapping Data
Type: Carbon
Dry properties (design values)
Thickness, t = 1.00
Tensile Strength, $f_{fu} = 840.00$
Tensile Modulus, $E_f = 82000.00$
Elongation, $e_{fu} = 0.009$
Number of directions, NoDir = 1
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, M = -407714.86
Shear Force, V2 = -3417.76
Shear Force, V3 = 187.9626
Axial Force, F = -9508.222
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1900.664$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 2007.478$
Mean Diameter of Tension Reinforcement, $DbL = 17.25$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.03499818$
 $u = y + p = 0.03499818$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00499818$ ((4.29), Biskinis Phd))
 $M_y = 3.7224E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2169.127
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.3849E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 33.00$
 $N = 9508.222$
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.4401709E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b/l_d)^{2/3}) = 311.2112$
 $d = 558.00$
 $y = 0.37195426$
 $A = 0.03417974$
 $B = 0.02205173$

with $p_t = 0.01362483$
 $p_c = 0.00594538$
 $p_v = 0.01439052$
 $N = 9508.222$
 $b = 250.00$
 $\rho = 0.07706093$
 $y_{comp} = 1.0794825E-005$
 with $f_c^* (12.3, (ACI 440)) = 33.51939$
 $f_c = 33.00$
 $f_l = 0.77310341$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $A_g = 237500.00$
 $g = p_t + p_c + p_v = 0.03396073$
 $r_c = 40.00$
 $A_e/A_c = 0.21429949$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.00$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.009$
 $E_f = 82000.00$
 $E_c = 26999.444$
 $y = 0.37099155$
 $A = 0.03380823$
 $B = 0.02183272$
 with $E_s = 200000.00$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 - Calculation of p -

 From table 10-8: $p = 0.03$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$

shear control ratio $V_y E / V_{col} O E = 0.73796687$

$d = 558.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1460.00$, is the total length of all stirrups parallel to loading (shear) direction

The term $2 * t_f / b_w * (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 * t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$N_{UD} = 9508.222$

$A_g = 237500.00$

$f_c E = 33.00$

$f_{yt} E = f_{yl} E = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.03396073$

$b = 250.00$

$d = 558.00$

$f_c E = 33.00$

 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

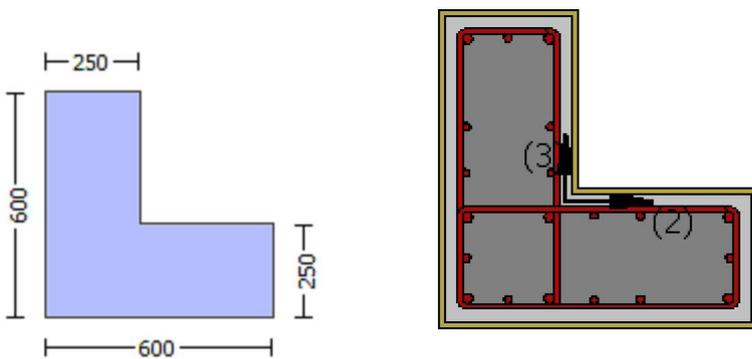
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

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: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of 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).

New material: Concrete Strength, $f_c = f_{cm} = 33.00$

New material: Steel Strength, $f_s = f_{sm} = 555.56$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = l_b/d = 0.30$

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

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, $M_a = -407714.86$

Shear Force, $V_a = 187.9626$

EDGE -B-

Bending Moment, $M_b = -155500.631$

Shear Force, $V_b = -187.9626$

BOTH EDGES

Axial Force, $F = -9508.222$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_{lt} = 0.00$

-Compression: $As_{lc} = 4737.522$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{l,ten} = 1900.664$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 2007.478$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.25$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 * V_n = 474261.328$

V_n ((10.3), ASCE 41-17) = $k_n * V_{CoI0} = 474261.328$

$V_{CoI} = 474261.328$

$k_n = 1.00$

$displacement_ductility_demand = 0.00363364$

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)

$f'_c = 25.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 407714.86$

$V_u = 187.9626$

$d = 0.8 * h = 480.00$

$N_u = 9508.222$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 534070.751$

where:

$V_{s1} = 376991.118$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.20833333$

$V_{s2} = 157079.633$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 $V_f((11-3)-(11.4), ACI 440) = 365392.00$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 $\ln(11.3) \sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where 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: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.00$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe}((11-5), ACI 440) = 328.00$
 $E_f = 82000.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.009$
 From (11-11), ACI 440: $V_s + V_f \leq 398582.298$
 $bw = 250.00$

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 $\theta = 1.8161592E-005$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00499818$ ((4.29), Biskinis Phd)
 $M_y = 3.7224E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2169.127
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 5.3849E+013$
 $\text{factor} = 0.30$
 $A_g = 237500.00$
 $f_c' = 33.00$
 $N = 9508.222$
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment M_y

Calculation of δ and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.4401709E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$
 $d = 558.00$
 $y = 0.37195426$
 $A = 0.03417974$
 $B = 0.02205173$
 with $pt = 0.01362483$
 $pc = 0.00594538$
 $pv = 0.01439052$
 $N = 9508.222$
 $b = 250.00$
 $\theta = 0.07706093$
 $y_{comp} = 1.0794825E-005$
 with $f_c'((12.3), (ACI 440)) = 33.51939$
 $f_c = 33.00$
 $f_l = 0.77310341$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $A_g = 237500.00$
 $g = pt + pc + pv = 0.03396073$
 $rc = 40.00$

$$A_e/A_c = 0.21429949$$

$$\text{Effective FRP thickness, } t_f = NL * t * \cos(b_1) = 1.00$$

$$\text{effective strain from (12.5) and (12.12), } \epsilon_{fe} = 0.004$$

$$f_u = 0.009$$

$$E_f = 82000.00$$

$$E_c = 26999.444$$

$$y = 0.37099155$$

$$A = 0.03380823$$

$$B = 0.02183272$$

$$\text{with } E_s = 200000.00$$

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: (a)

Calculation No. 12

column C1, Floor 1

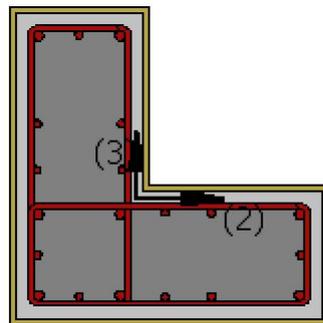
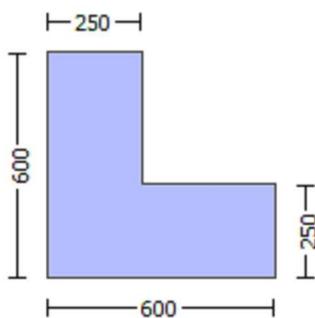
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\phi = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

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 = 1.06737
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
FRP Wrapping Data
Type: Carbon
Dry properties (design values)
Thickness, $t = 1.00$
Tensile Strength, $f_{fu} = 840.00$
Tensile Modulus, $E_f = 82000.00$
Elongation, $e_{fu} = 0.009$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 0.14056349$
EDGE -B-
Shear Force, $V_b = -0.14056349$
BOTH EDGES
Axial Force, $F = -8933.736$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1900.664$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.73796687$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 6.0294E+008$
 $M_{u1+} = 6.0294E+008$, 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
 $M_{u1-} = 3.2075E+008$, 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 6.0294E+008$$

$M_{u2+} = 6.0294E+008$, 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

$M_{u2-} = 3.2075E+008$, 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:

$$\phi_u = 1.3372380E-005$$

$$M_u = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01247586$$

$$\phi_{we} \text{ ((5.4c), TBDY)} = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05035379$$

where $\phi = a_f * \phi_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$\phi_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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).

$$\phi_{sh, \min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\text{psh,x ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * \text{s}) = 0.00482813$$

Lstir (Length of stirrups along Y) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

$$\text{psh,y ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * \text{s}) = 0.00482813$$

Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

$$\text{s} = 100.00$$

$$\text{fywe} = 694.45$$

$$\text{fce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: cc} = 0.00267374$$

$$\text{c} = \text{confinement factor} = 1.06737$$

$$\text{y1} = 0.00140044$$

$$\text{sh1} = 0.0044814$$

$$\text{ft1} = 466.8167$$

$$\text{fy1} = 389.0139$$

$$\text{su1} = 0.00512$$

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

$$\text{lo/lou,min} = \text{lb/ld} = 0.30$$

$$\text{su1} = 0.4 * \text{esu1_nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: esu1_nominal} = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fs1} = \text{fs} = 389.0139$$

$$\text{with Es1} = \text{Es} = 200000.00$$

$$\text{y2} = 0.00140044$$

$$\text{sh2} = 0.0044814$$

$$\text{ft2} = 466.8167$$

$$\text{fy2} = 389.0139$$

$$\text{su2} = 0.00512$$

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

$$\text{lo/lou,min} = \text{lb/lb,min} = 0.30$$

$$\text{su2} = 0.4 * \text{esu2_nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: esu2_nominal} = 0.08,$$

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fs2} = \text{fs} = 389.0139$$

$$\text{with Es2} = \text{Es} = 200000.00$$

$$\text{yv} = 0.00140044$$

$$\text{shv} = 0.0044814$$

$$\text{ftv} = 466.8167$$

$$\text{fyv} = 389.0139$$

$$\text{suv} = 0.00512$$

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

$$\text{lo/lou,min} = \text{lb/ld} = 0.30$$

$$\text{suv} = 0.4 * \text{esuv_nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: esuv_nominal} = 0.08,$$

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, are also multiplied by $\text{Min}(1, 1.25 * (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fsv} = \text{fs} = 389.0139$$

$$\text{with Esv} = \text{Es} = 200000.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16061358$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07008593$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1696398$$

and confined core properties:

$$b = 190.00$$

$$d = 528.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 35.22334$$

$$c_c (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22334125$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.097458$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23589266$$

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

--->

$$s_u (4.8) = 0.31383738$$

$$\mu_u = M_{Rc} (4.15) = 6.0294E+008$$

$$u = s_u (4.1) = 1.3372380E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_{u1} -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0927237E-005$$

$$\mu_u = 3.2075E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 42.00$$

$$v = 0.00081005$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

bmax = 600.00
hmax = 600.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008$
bw = 250.00
effective stress from (A.35), $ff,e = 720.2618$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.00$
 $f_{u,f} = 840.00$
 $E_f = 82000.00$
 $u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$
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).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00482813$

Expression ((5.4d), TBDY) for $psh_{,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

s = 100.00
 $f_{ywe} = 694.45$
f_{ce} = 33.00

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$
c = confinement factor = 1.06737

$y_1 = 0.00140044$
 $sh_1 = 0.0044814$

$ft_1 = 466.8167$
 $fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$
 $sh_2 = 0.0044814$

$ft_2 = 466.8167$
 $fy_2 = 389.0139$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$$su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2_nominal} = 0.08$,

For calculation of $esu_{2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 389.0139$$

$$\text{with } Es_2 = Es = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 0.30$$

$$su_v = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and yv, shv, ftv, fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.0292549$$

$$2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.06704247$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$fcc (5A.2, TBDY) = 35.22334$$

$$cc (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.03435585$$

$$2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.07873215$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.15879007$$

$$Mu = MRc (4.14) = 3.2075E+008$$

$$u = su (4.1) = 1.0927237E-005$$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.3372380E-005$$

$$Mu = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$\text{we ((5.4c), TBDY)} = a_s e * s_h \cdot \min(f_{ywe}/f_{ce} + \text{Min}(f_x, f_y)) = 0.05035379$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$$

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)

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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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$f_{y1} = 389.0139$
 $s_{u1} = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30$
 $s_{u1} = 0.4 * e_{su1,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{su1,nominal} = 0.08$,
 For calculation of $e_{su1,nominal}$ and y_1, sh_1, ft_1, f_{y1} , it is considered
 characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s1} = f_s = 389.0139$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00140044$
 $sh_2 = 0.0044814$
 $ft_2 = 466.8167$
 $f_{y2} = 389.0139$
 $s_{u2} = 0.00512$
 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
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$
 $s_{u2} = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,
 For calculation of $e_{su2,nominal}$ and y_2, sh_2, ft_2, f_{y2} , it is considered
 characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_2, sh_2, ft_2, f_{y2} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 389.0139$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00140044$
 $sh_v = 0.0044814$
 $ft_v = 466.8167$
 $f_{yv} = 389.0139$
 $s_{uv} = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30$
 $s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,
 considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, f_{yv} , it is considered
 characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 389.0139$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.16061358$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07008593$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.1696398$
 and confined core properties:
 $b = 190.00$
 $d = 528.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.22334125$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.097458$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.23589266$
 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
 --->
 $s_u (4.8) = 0.31383738$

$$\begin{aligned} \mu_u &= M/R_c(4.15) = 6.0294E+008 \\ u &= s_u(4.1) = 1.3372380E-005 \end{aligned}$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of μ_u

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$\begin{aligned} u &= 1.0927237E-005 \\ \mu_u &= 3.2075E+008 \end{aligned}$$

with full section properties:

$$\begin{aligned} b &= 600.00 \\ d &= 557.00 \\ d' &= 42.00 \\ v &= 0.00081005 \\ N &= 8933.736 \\ f_c &= 33.00 \\ c_o(5A.5, TBDY) &= 0.002 \\ \text{Final value of } \mu_u: \mu_u^* &= \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01247586 \\ \text{The Shear_factor is considered equal to 1 (pure moment strength)} \\ \text{From (5.4b), TBDY: } \mu_u &= 0.01247586 \\ \mu_{we}((5.4c), TBDY) &= a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379 \\ \text{where } f &= a_f * p_f * f_{fe}/f_{ce} \text{ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)} \end{aligned}$$

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.27151783$$

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.

AnoConf = 105733.333 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00482813$

Expression ((5.4d), TBDY) for psh_{min} has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

$c =$ confinement factor = 1.06737

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{min} = lb/ld = 0.30$

$su_1 = 0.4 * esu_{1_nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{min} = lb/lb_{min} = 0.30$

$su_2 = 0.4 * esu_{2_nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 389.0139$

with $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{min} = lb/ld = 0.30$

$su_v = 0.4 * esu_{v_nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{v_nominal} = 0.08$,

considering characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY

For calculation of $esu_{v_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 389.0139$

with $E_{sv} = E_s = 200000.00$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0292549$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.06704247$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07081015$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 12.00$

$f_{cc} (5A.2, TBDY) = 35.22334$

$cc (5A.5, TBDY) = 0.00267374$

$c = \text{confinement factor} = 1.06737$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03435585$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07873215$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08315676$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

$\mu_u (4.9) = 0.15879007$

$\mu_u = MR_c (4.14) = 3.2075E+008$

$u = \mu_u (4.1) = 1.0927237E-005$

Calculation of ratio lb/d

Inadequate Lap Length with $lb/d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$

$V_{r1} = V_{c0} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{c0}$

$V_{c0} = 631439.816$

$k_{nl} = 1$ (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)

$f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/d = 2.00$

$\mu_u = 90.31778$

$V_u = 0.14056349$

$d = 0.8 \cdot h = 480.00$

$N_u = 8933.736$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$

where:

$V_{s1} = 418882.372$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.20833333$

$V_{s2} = 174534.321$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.50$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 365392.00$$

$f = 0.95$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$

$V_f = \text{Min}(|V_f(45^\circ, \alpha)|, |V_f(-45^\circ, \alpha)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.00$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

f_{fe} ((11-5), ACI 440) = 328.00

$E_f = 82000.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.009$

From (11-11), ACI 440: $V_s + V_f \leq 457936.196$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$

$V_{Col0} = 544688.006$

$k_{nl} = 1$ (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).

$\rho = 1$ (normal-weight concrete)

$f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 330.5734$

$V_u = 0.14056349$

$d = 0.8 * h = 480.00$

$N_u = 8933.736$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$

where:

$V_{s1} = 418882.372$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.20833333$

$V_{s2} = 174534.321$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.50$

V_f ((11-3)-(11.4), ACI 440) = 365392.00

$f = 0.95$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$

$V_f = \text{Min}(|V_f(45^\circ, \alpha)|, |V_f(-45^\circ, \alpha)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.00$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

f_{fe} ((11-5), ACI 440) = 328.00

$E_f = 82000.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.009$

From (11-11), ACI 440: $V_s + V_f \leq 457936.196$

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

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 = 1.06737

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{o,min} = 0.30$

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

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, $V_a = 0.14056349$

EDGE -B-

Shear Force, $V_b = -0.14056349$

BOTH EDGES

Axial Force, $F = -8933.736$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 4737.522$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $Asl,ten = 1900.664$
-Compression: $Asl,com = 829.3805$
-Middle: $Asl,mid = 2007.478$

Calculation of Shear Capacity ratio, $Ve/Vr = 0.73796687$

Member Controlled by Flexure ($Ve/Vr < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $Ve = (Mpr1 + Mpr2)/ln = 401961.704$

with

$Mpr1 = \text{Max}(Mu1+, Mu1-) = 6.0294E+008$

$Mu1+ = 6.0294E+008$, 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

$Mu1- = 3.2075E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$Mpr2 = \text{Max}(Mu2+, Mu2-) = 6.0294E+008$

$Mu2+ = 6.0294E+008$, 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

$Mu2- = 3.2075E+008$, 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 u according to 4.1, Biskinis/Fardis 2013:

$u = 1.3372380E-005$

$Mu = 6.0294E+008$

with full section properties:

$b = 250.00$

$d = 558.00$

$d' = 43.00$

$v = 0.00194064$

$N = 8933.736$

$fc = 33.00$

$co (5A.5, TBDY) = 0.002$

Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01247586$

we ((5.4c), TBDY) = $ase * sh, \text{min} * fywe / fce + \text{Min}(fx, fy) = 0.05035379$

where $f = af * pf * ffe / fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$fx = 0.04207769$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.24098246$

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), $pf = 2tf / bw = 0.008$

$bw = 250.00$

effective stress from (A.35), $ff,e = 720.2618$

$fy = 0.04207769$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.24098246$

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), $pf = 2tf / bw = 0.008$

$bw = 250.00$

effective stress from (A.35), $ff,e = 720.2618$

$R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.00$

$f_{u,f} = 840.00$
 $E_f = 82000.00$
 $u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

 $s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

$c = \text{confinement factor} = 1.06737$

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su_1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$su_2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2 , sh_2 , ft_2 , fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 389.0139$

with $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$shv = 0.0044814$
 $ftv = 466.8167$
 $fyv = 389.0139$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.30$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv , shv,ftv,fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 389.0139$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.16061358$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.07008593$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.1696398$
 and confined core properties:
 $b = 190.00$
 $d = 528.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = confinement\ factor = 1.06737$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.22334125$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.097458$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.23589266$
 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
 --->
 $su (4.8) = 0.31383738$
 $Mu = MRc (4.15) = 6.0294E+008$
 $u = su (4.1) = 1.3372380E-005$

 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:

$u = 1.0927237E-005$
 $Mu = 3.2075E+008$

 with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 42.00$
 $v = 0.00081005$
 $N = 8933.736$
 $fc = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.01247586$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01247586$
 $ve ((5.4c), TBDY) = ase * sh,min*fywe/fce + Min(fx, fy) = 0.05035379$

where $f = af \cdot pf \cdot ffe / fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.04207769$$

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), $pf = 2tf/bw = 0.008$

$$bw = 250.00$$

effective stress from (A.35), $ffe = 720.2618$

$$fy = 0.04207769$$

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), $pf = 2tf/bw = 0.008$

$$bw = 250.00$$

effective stress from (A.35), $ffe = 720.2618$

$$R = 40.00$$

Effective FRP thickness, $tf = NL \cdot t \cdot \cos(b1) = 1.00$

$$fu,f = 840.00$$

$$Ef = 82000.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) \cdot (A_{conf,min}/A_{conf,max}), 0) = 0.27151783$$

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 $b^2/6$ as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00482813$$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh,x \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$psh,y \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$fywe = 694.45$$

$$fce = 33.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

$$c = \text{confinement factor} = 1.06737$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$$lo/lo_{u,min} = lb/ld = 0.30$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 389.0139$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.30$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

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 $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 389.0139$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.30$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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.

yv, shv, ftv, fyv , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.0292549$$

$$2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.06704247$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$fcc (5A.2, TBDY) = 35.22334$$

$$cc (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.03435585$$

$$2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.07873215$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs, y2$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.15879007$$

$$Mu = MRc (4.14) = 3.2075E+008$$

$$u = su (4.1) = 1.0927237E-005$$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu2+

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.3372380E-005$$

$$Mu = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $p_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00482813
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00
fywe = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00267374
c = confinement factor = 1.06737

y1 = 0.00140044
sh1 = 0.0044814
ft1 = 466.8167
fy1 = 389.0139
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044
sh2 = 0.0044814
ft2 = 466.8167
fy2 = 389.0139
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044
shv = 0.0044814
ftv = 466.8167
fyv = 389.0139
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16061358

2 = Asl,com/(b*d)*(fs2/fc) = 0.07008593

v = Asl,mid/(b*d)*(fsv/fc) = 0.1696398

and confined core properties:

b = 190.00

$d = 528.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22334125$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.097458$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23589266$
 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
 --->

$s_u (4.8) = 0.31383738$
 $\mu_u = M R_c (4.15) = 6.0294E+008$
 $u = s_u (4.1) = 1.3372380E-005$

 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 u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.0927237E-005$
 $\mu_u = 3.2075E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 42.00$
 $v = 0.00081005$
 $N = 8933.736$
 $f_c = 33.00$
 $cc (5A.5, TBDY) = 0.002$
 Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, cc) = 0.01247586$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $c_u = 0.01247586$
 $w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$
 where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04207769$
 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), $p_f = 2t_f/b_w = 0.008$
 $b_w = 250.00$
 effective stress from (A.35), $f_{f,e} = 720.2618$

$f_y = 0.04207769$
 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), $p_f = 2t_f/b_w = 0.008$
 $b_w = 250.00$
 effective stress from (A.35), $f_{f,e} = 720.2618$

R = 40.00

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

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)

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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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00482813$

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) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00482813$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su_1 = 0.4 \cdot esu_{1,nominal}$ ((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 $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$su_2 = 0.4 \cdot esu_{2,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s2} = f_s = 389.0139$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00140044$
 $sh_v = 0.0044814$
 $ft_v = 466.8167$
 $fy_v = 389.0139$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 389.0139$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.0292549$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.06704247$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.07081015$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 12.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.03435585$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07873215$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.08315676$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->

$su (4.9) = 0.15879007$
 $Mu = MRc (4.14) = 3.2075E+008$
 $u = su (4.1) = 1.0927237E-005$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

 Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$
 $V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 631439.816$
 $knl = 1$ (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)
 $f_c' = 33.00$, but $f_c'^{0.5} <= 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $Mu = 90.32855$
 $Vu = 0.14056349$
 $d = 0.8 * h = 480.00$
 $Nu = 8933.736$
 $Ag = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$

where:

$V_{s1} = 174534.321$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.50$

$V_{s2} = 418882.372$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.20833333$

V_f ((11-3)-(11.4), ACI 440) = 365392.00

$f = 0.95$, 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: $\theta = 45^\circ$

$V_f = \text{Min}(|V_f(45^\circ)|, |V_f(-45^\circ)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.00$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

f_{fe} ((11-5), ACI 440) = 328.00

$E_f = 82000.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.009$

From (11-11), ACI 440: $V_s + V_f \leq 457936.196$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{Col0}$

$V_{Col0} = 544688.006$

$k_n l = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f \cdot V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)

$f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 330.5627$

$\nu_u = 0.14056349$

$d = 0.8 \cdot h = 480.00$

$N_u = 8933.736$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$

where:

$V_{s1} = 174534.321$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.50$

$V_{s2} = 418882.372$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.20833333$

Vf ((11-3)-(11.4), ACI 440) = 365392.00

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(θ), is implemented for every different fiber orientation ai, as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, 1)|, |Vf(-45, a1)|), with:

total thickness per orientation, tf1 = NL*t/NoDir = 1.00

dfv = d (figure 11.2, ACI 440) = 557.00

ffe ((11-5), ACI 440) = 328.00

Ef = 82000.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.009

From (11-11), ACI 440: Vs + Vf <= 457936.196

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

Number of directions, NoDir = 1

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, NL = 1

Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, $M = -1.0439E+007$
Shear Force, $V2 = -3417.76$
Shear Force, $V3 = 187.9626$
Axial Force, $F = -9508.222$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{,ten} = 1900.664$
-Compression: $As_{,com} = 829.3805$
-Middle: $As_{,mid} = 2007.478$
Mean Diameter of Tension Reinforcement, $Db_L = 17.25$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.03703787$
 $u = y + p = 0.03703787$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00703787$ ((4.29), Biskinis Phd))
 $M_y = 3.7224E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3054.316
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.3849E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 33.00$
 $N = 9508.222$
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{,ten}, y_{,com})$
 $y_{,ten} = 4.4401709E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 311.2112$
 $d = 558.00$
 $y = 0.37195426$
 $A = 0.03417974$
 $B = 0.02205173$
with $pt = 0.01362483$
 $pc = 0.00594538$
 $p_v = 0.01439052$
 $N = 9508.222$
 $b = 250.00$
 $" = 0.07706093$
 $y_{,comp} = 1.0794825E-005$
with f_c^* (12.3, (ACI 440)) = 33.51939
 $f_c = 33.00$
 $f_l = 0.77310341$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $A_g = 237500.00$
 $g = pt + pc + p_v = 0.03396073$
 $rc = 40.00$
 $A_e / A_c = 0.21429949$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.00$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.009$
 $E_f = 82000.00$
 $E_c = 26999.444$
 $y = 0.37099155$

A = 0.03380823
B = 0.02183272
with Es = 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: $\rho = 0.03$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_{yE}/V_{CoIE} = 0.73796687$

$d = 558.00$

$s = 0.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2*t_f/b_w*(f_{fe}/f_s)$ is implemented to account for FRP contribution

where $f = 2*t_f/b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe}/f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$N_{UD} = 9508.222$

$A_g = 237500.00$

$f_{cE} = 33.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.03396073$

$b = 250.00$

$d = 558.00$

$f_{cE} = 33.00$

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

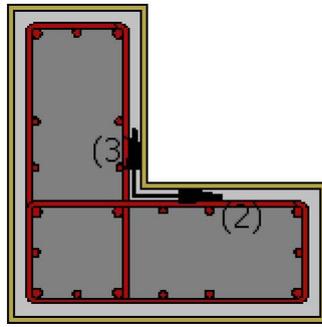
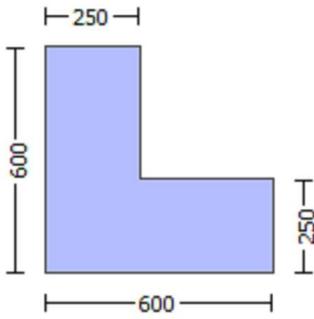
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of 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).

New material: Concrete Strength, $f_c = f_{cm} = 33.00$

New material: Steel Strength, $f_s = f_{sm} = 555.56$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{o,min} = l_b/d = 0.30$

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -1.0439E+007$

Shear Force, $V_a = -3417.76$

EDGE -B-

Bending Moment, Mb = 183142.393

Shear Force, Vb = 3417.76

BOTH EDGES

Axial Force, F = -9508.222

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: Aslt = 0.00

-Compression: Aslc = 4737.522

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten = 1900.664

-Compression: Asl,com = 829.3805

-Middle: Asl,mid = 2007.478

Mean Diameter of Tension Reinforcement, DbL,ten = 17.25

New component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = 1.0*Vn = 549940.358

Vn ((10.3), ASCE 41-17) = knl*VCol0 = 549940.358

VCol = 549940.358

knl = 1.00

displacement_ductility_demand = 0.04393019

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' = 25.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 183142.393

Vu = 3417.76

d = 0.8*h = 480.00

Nu = 9508.222

Ag = 150000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 534070.751

where:

Vs1 = 157079.633 is calculated for section web, with:

d = 200.00

Av = 157079.633

fy = 500.00

s = 100.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.50

Vs2 = 376991.118 is calculated for section flange, with:

d = 480.00

Av = 157079.633

fy = 500.00

s = 100.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.20833333

Vf ((11-3)-(11.4), ACI 440) = 365392.00

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 Vf(θ , α), is implemented for every different fiber orientation ai,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, θ)|, |Vf(-45, θ)|), with:

total thickness per orientation, tf1 = NL*t/NoDir = 1.00

dfv = d (figure 11.2, ACI 440) = 557.00

ffe ((11-5), ACI 440) = 328.00

Ef = 82000.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.009

From (11-11), ACI 440: Vs + Vf <= 398582.298

bw = 250.00

displacement_ductility_demand is calculated as ϕ / y

- Calculation of ϕ / y for END B -
for rotation axis 3 and integ. section (b)

From analysis, chord rotation = $3.0367663E-005$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00069127$ ((4.29), Biskinis Phd))
 $M_y = 3.7224E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.3849E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 33.00$
 $N = 9508.222$
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment M_y

Calculation of ϕ and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.4401709E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 311.2112$
 $d = 558.00$
 $y = 0.37195426$
 $A = 0.03417974$
 $B = 0.02205173$
with $pt = 0.01362483$
 $pc = 0.00594538$
 $pv = 0.01439052$
 $N = 9508.222$
 $b = 250.00$
 $" = 0.07706093$
 $y_{comp} = 1.0794825E-005$
with $f_c' (12.3, (ACI 440)) = 33.51939$
 $f_l = 0.77310341$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $A_g = 237500.00$
 $g = pt + pc + pv = 0.03396073$
 $rc = 40.00$
 $A_e / A_c = 0.21429949$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.00$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.009$
 $E_f = 82000.00$
 $E_c = 26999.444$
 $y = 0.37099155$
 $A = 0.03380823$
 $B = 0.02183272$
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. 14

column C1, Floor 1

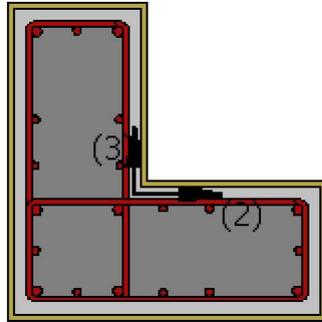
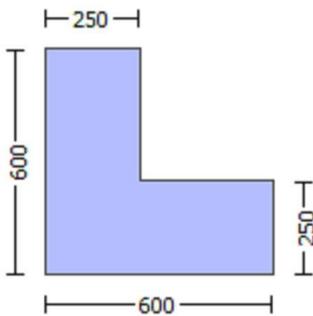
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

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 = 1.06737

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$
FRP Wrapping Data
Type: Carbon
Dry properties (design values)
Thickness, $t = 1.00$
Tensile Strength, $f_{fu} = 840.00$
Tensile Modulus, $E_f = 82000.00$
Elongation, $e_{fu} = 0.009$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 0.14056349$
EDGE -B-
Shear Force, $V_b = -0.14056349$
BOTH EDGES
Axial Force, $F = -8933.736$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1900.664$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 2007.478$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.73796687$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 6.0294E+008$
 $Mu_{1+} = 6.0294E+008$, 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
 $Mu_{1-} = 3.2075E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 6.0294E+008$
 $Mu_{2+} = 6.0294E+008$, 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
 $Mu_{2-} = 3.2075E+008$, 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:
 $\phi_u = 1.3372380E-005$
 $M_u = 6.0294E+008$

with full section properties:
 $b = 250.00$
 $d = 558.00$
 $d' = 43.00$
 $v = 0.00194064$

$$N = 8933.736$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$\text{we ((5.4c), TBDY)} = a_s e^* s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $p_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 389.0139$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 389.0139$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.16061358$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.07008593$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.1696398$$

and confined core properties:

$$b = 190.00$$

$$d = 528.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 35.22334$$

$$cc (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.22334125$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.097458$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.23589266$$

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) = 0.31383738
Mu = MRc (4.15) = 6.0294E+008
u = su (4.1) = 1.3372380E-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 = 1.0927237E-005
Mu = 3.2075E+008

with full section properties:

b = 600.00
d = 557.00
d' = 42.00
v = 0.00081005
N = 8933.736
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01247586
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01247586
ve ((5.4c), TBDY) = ase* sh,min*fywe/fce+ Min(fx, fy) = 0.05035379
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.04207769

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.24098246

with Unconfined area = ((bmax-2R)^2+ (hmax-2R)^2)/3 = 57233.333

bmax = 600.00

hmax = 600.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008

bw = 250.00

effective stress from (A.35), ff,e = 720.2618

fy = 0.04207769

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.24098246

with Unconfined area = ((bmax-2R)^2+ (hmax-2R)^2)/3 = 0.00

bmax = 600.00

hmax = 600.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008

bw = 250.00

effective stress from (A.35), ff,e = 720.2618

R = 40.00

Effective FRP thickness, tf = NL*t*Cos(b1) = 1.00

fu,f = 840.00

Ef = 82000.00

u,f = 0.015

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.27151783

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 169100.00 is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

 $s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

$c = \text{confinement factor} = 1.06737$

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su_1 = 0.4 * esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$su_2 = 0.4 * esu_{2,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 389.0139$

with $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su_v = 0.4 * esu_{v,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{v,nominal} = 0.08$,

considering characteristic value $fsy_v = fs_v/1.2$, from table 5.1, TBDY

For calculation of $esu_{v,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 389.0139$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0292549$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.06704247$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07081015$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 12.00$

f_{cc} (5A.2, TBDY) = 35.22334

cc (5A.5, TBDY) = 0.00267374

c = confinement factor = 1.06737

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03435585$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.07873215$

$v = Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08315676$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.15879007

$Mu = MRc$ (4.14) = 3.2075E+008

$u = su$ (4.1) = 1.0927237E-005

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 1.3372380E-005$

$Mu = 6.0294E+008$

with full section properties:

$b = 250.00$

$d = 558.00$

$d' = 43.00$

$v = 0.00194064$

$N = 8933.736$

$f_c = 33.00$

co (5A.5, TBDY) = 0.002

Final value of cu : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01247586$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01247586$

w_e ((5.4c), TBDY) = $ase \cdot sh_{min} \cdot fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.05035379$

where $f = af \cdot pf \cdot f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $fx = 0.04207769$

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), $pf = 2tf/bw = 0.008$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 720.2618$

 $fy = 0.04207769$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

af = 0.24098246
with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$
bmax = 600.00
hmax = 600.00
From EC8 A.4.4.3(6), pf = $2t_f/b_w = 0.008$
bw = 250.00
effective stress from (A.35), ff,e = 720.2618

R = 40.00
Effective FRP thickness, tf = $NL*t*Cos(b1) = 1.00$
fu,f = 840.00
Ef = 82000.00
u,f = 0.015

ase = $Max(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.27151783$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 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 = $Min(psh,x, psh,y) = 0.00482813$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$
Lstir (Length of stirrups along Y) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 100.00
fywe = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00267374
c = confinement factor = 1.06737

y1 = 0.00140044
sh1 = 0.0044814

ft1 = 466.8167
fy1 = 389.0139

su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/ld = 0.30

su1 = $0.4*es_{1_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: es_{1_nominal} = 0.08,

For calculation of es_{1_nominal} and y1, sh1,ft1,fy1, it is considered characteristic value fs_{y1} = fs_{1/1.2}, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $Min(1,1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs₁ = fs = 389.0139

with Es₁ = Es = 200000.00

y2 = 0.00140044
sh2 = 0.0044814

ft2 = 466.8167
fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/ld = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16061358

2 = Asl,com/(b*d)*(fs2/fc) = 0.07008593

v = Asl,mid/(b*d)*(fsv/fc) = 0.1696398

and confined core properties:

b = 190.00

d = 528.00

d' = 13.00

fcc (5A.2, TBDY) = 35.22334

cc (5A.5, TBDY) = 0.00267374

c = confinement factor = 1.06737

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22334125

2 = Asl,com/(b*d)*(fs2/fc) = 0.097458

v = Asl,mid/(b*d)*(fsv/fc) = 0.23589266

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) = 0.31383738

Mu = MRc (4.15) = 6.0294E+008

u = su (4.1) = 1.3372380E-005

Calculation of ratio lb/ld

Inadequate Lap Length with lb/ld = 0.30

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.0927237E-005

Mu = 3.2075E+008

with full section properties:

b = 600.00

d = 557.00

d' = 42.00

v = 0.00081005

N = 8933.736

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01247586$

we ((5.4c), TBDY) = $ase * sh_{,min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.05035379$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.04207769

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

af = 0.24098246

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$

bmax = 600.00

hmax = 600.00

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.008$

bw = 250.00

effective stress from (A.35), $ff_{,e} = 720.2618$

fy = 0.04207769

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

af = 0.24098246

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$

bmax = 600.00

hmax = 600.00

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.008$

bw = 250.00

effective stress from (A.35), $ff_{,e} = 720.2618$

R = 40.00

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.00$

fu,f = 840.00

Ef = 82000.00

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 $bi^2/6$ as defined at (A.2).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00482813$

Expression ((5.4d), TBDY) for $psh_{,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 psh_x ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

$fy_{we} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

$c = \text{confinement factor} = 1.06737$
 $y1 = 0.00140044$
 $sh1 = 0.0044814$
 $ft1 = 466.8167$
 $fy1 = 389.0139$
 $su1 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/ld = 0.30$
 $su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fs1 = fs = 389.0139$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00140044$
 $sh2 = 0.0044814$
 $ft2 = 466.8167$
 $fy2 = 389.0139$
 $su2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/lb, \text{min} = 0.30$
 $su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fs2 = fs = 389.0139$
 with $Es2 = Es = 200000.00$
 $yv = 0.00140044$
 $shv = 0.0044814$
 $ftv = 466.8167$
 $fyv = 389.0139$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \text{min} = lb/ld = 0.30$
 $suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 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 $fsv = fs = 389.0139$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.0292549$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.06704247$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.07081015$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 12.00$
 $fcc (5A.2, \text{TBDY}) = 35.22334$
 $cc (5A.5, \text{TBDY}) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.03435585$
 $2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.07873215$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.08315676$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.15879007$$

$$M_u = MR_c(4.14) = 3.2075E+008$$

$$u = s_u(4.1) = 1.0927237E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$

$$V_{r1} = V_{c0} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{c0}$$

$$V_{c0} = 631439.816$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs + f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$$f'_c = 33.00, \text{ but } f'_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$M_u = 90.31778$$

$$V_u = 0.14056349$$

$$d = 0.8 \cdot h = 480.00$$

$$N_u = 8933.736$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 593416.693$$

where:

$V_{s1} = 418882.372$ is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

V_{s1} is multiplied by $\text{Col1} = 1.00$

$$s/d = 0.20833333$$

$V_{s2} = 174534.321$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

V_{s2} is multiplied by $\text{Col2} = 1.00$

$$s/d = 0.50$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 365392.00$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \alpha_1 = \alpha_1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L \cdot t / N_{oDir} = 1.00$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 557.00$$

$$f_{fe} \text{ ((11-5), ACI 440)} = 328.00$$

$$E_f = 82000.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.009$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 457936.196$$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$

$$Vr2 = VCol \text{ ((10.3), ASCE 41-17)} = knl * VCol0$$

$$VCol0 = 544688.006$$

$$knl = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$fc' = 33.00, \text{ but } fc^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$Mu = 330.5734$$

$$Vu = 0.14056349$$

$$d = 0.8 * h = 480.00$$

$$Nu = 8933.736$$

$$Ag = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } Vs = Vs1 + Vs2 = 593416.693$$

where:

Vs1 = 418882.372 is calculated for section web, with:

$$d = 480.00$$

$$Av = 157079.633$$

$$fy = 555.56$$

$$s = 100.00$$

Vs1 is multiplied by Col1 = 1.00

$$s/d = 0.20833333$$

Vs2 = 174534.321 is calculated for section flange, with:

$$d = 200.00$$

$$Av = 157079.633$$

$$fy = 555.56$$

$$s = 100.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.50$$

$$Vf \text{ ((11-3)-(11.4), ACI 440)} = 365392.00$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc) \sin \alpha$ which is more a generalised expression,

where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $Vf(\alpha, a1)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \alpha = b1 + 90^\circ = 90.00$$

$$Vf = \text{Min}(|Vf(45, a1)|, |Vf(-45, a1)|), \text{ with:}$$

$$\text{total thickness per orientation, } tf1 = NL * t / \text{NoDir} = 1.00$$

$$dfv = d \text{ (figure 11.2, ACI 440)} = 557.00$$

$$ffe \text{ ((11-5), ACI 440)} = 328.00$$

$$Ef = 82000.00$$

$$fe = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } fu = 0.009$$

$$\text{From (11-11), ACI 440: } Vs + Vf \leq 457936.196$$

$$bw = 250.00$$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Secondary Member: Concrete Strength, $fc = fcm = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

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 = 1.06737
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{o,min} = 0.30$
FRP Wrapping Data
Type: Carbon
Dry properties (design values)
Thickness, $t = 1.00$
Tensile Strength, $f_{fu} = 840.00$
Tensile Modulus, $E_f = 82000.00$
Elongation, $e_{fu} = 0.009$
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, $V_a = 0.14056349$
EDGE -B-
Shear Force, $V_b = -0.14056349$
BOTH EDGES
Axial Force, $F = -8933.736$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1900.664$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.73796687$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 6.0294E+008$
 $M_{u1+} = 6.0294E+008$, 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
 $M_{u1-} = 3.2075E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 6.0294E+008$
 $M_{u2+} = 6.0294E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the static loading combination
 $M_{u2-} = 3.2075E+008$, 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 u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.3372380E-005$$

$$Mu = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$$

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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $p_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

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 = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00267374
c = confinement factor = 1.06737

y1 = 0.00140044
sh1 = 0.0044814
ft1 = 466.8167
fy1 = 389.0139
su1 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139
with Es1 = Es = 200000.00

y2 = 0.00140044
sh2 = 0.0044814
ft2 = 466.8167
fy2 = 389.0139
su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139
with Es2 = Es = 200000.00

yv = 0.00140044
shv = 0.0044814
ftv = 466.8167
fyv = 389.0139
suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139
with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16061358
2 = Asl,com/(b*d)*(fs2/fc) = 0.07008593
v = Asl,mid/(b*d)*(fsv/fc) = 0.1696398

and confined core properties:

$b = 190.00$
 $d = 528.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22334125$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.097458$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23589266$
 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
 --->
 $su (4.8) = 0.31383738$
 $Mu = MRc (4.15) = 6.0294E+008$
 $u = su (4.1) = 1.3372380E-005$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

 Calculation of Mu_1 -

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.0927237E-005$
 $Mu = 3.2075E+008$

 with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 42.00$
 $v = 0.00081005$
 $N = 8933.736$
 $f_c = 33.00$
 $cc (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01247586$
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$
 where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04207769$
 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), $p_f = 2t_f/b_w = 0.008$
 $b_w = 250.00$
 effective stress from (A.35), $f_{f,e} = 720.2618$

 $f_y = 0.04207769$
 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), $p_f = 2t_f/b_w = 0.008$
 $b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \cos(b1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered

characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 389.0139$

with $Es1 = Es = 200000.00$

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30$

$su2 = 0.4 * esu2_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and $y2, sh2, ft2, fy2$, it is considered

characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 389.0139$

with $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 389.0139$

with $Es_v = Es = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.0292549$

2 = $Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.06704247$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.07081015$

and confined core properties:

b = 540.00

d = 527.00

d' = 12.00

fcc (5A.2, TBDY) = 35.22334

cc (5A.5, TBDY) = 0.00267374

c = confinement factor = 1.06737

1 = $Asl_{ten}/(b \cdot d) \cdot (fs_1/fc) = 0.03435585$

2 = $Asl_{com}/(b \cdot d) \cdot (fs_2/fc) = 0.07873215$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.08315676$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.15879007

$Mu = MRc$ (4.14) = 3.2075E+008

u = su (4.1) = 1.0927237E-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 = 1.3372380E-005

$Mu = 6.0294E+008$

with full section properties:

b = 250.00

d = 558.00

d' = 43.00

v = 0.00194064

N = 8933.736

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01247586$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01247586$

w_e ((5.4c), TBDY) = $ase * sh_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04207769$

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), $pf = 2tf / bw = 0.008$

$bw = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$f_y = 0.04207769$

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), $pf = 2tf / bw = 0.008$

$bw = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.27151783$

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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 389.0139

with Es1 = Es = 200000.00

y2 = 0.00140044

sh2 = 0.0044814

ft2 = 466.8167

fy2 = 389.0139

su2 = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.30

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 389.0139

with Es2 = Es = 200000.00

yv = 0.00140044

shv = 0.0044814

ftv = 466.8167

fyv = 389.0139

suv = 0.00512

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.30

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 389.0139

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16061358

2 = Asl,com/(b*d)*(fs2/fc) = 0.07008593

v = Asl,mid/(b*d)*(fsv/fc) = 0.1696398

and confined core properties:

b = 190.00

d = 528.00

d' = 13.00

fcc (5A.2, TBDY) = 35.22334

cc (5A.5, TBDY) = 0.00267374

c = confinement factor = 1.06737

1 = Asl,ten/(b*d)*(fs1/fc) = 0.22334125

2 = Asl,com/(b*d)*(fs2/fc) = 0.097458

v = Asl,mid/(b*d)*(fsv/fc) = 0.23589266

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) = 0.31383738

Mu = MRc (4.15) = 6.0294E+008

u = su (4.1) = 1.3372380E-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:

$$\mu = 1.0927237E-005$$

$$\mu_2 = 3.2075E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 42.00$$

$$v = 0.00081005$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$$

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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $p_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without

earthquake detailing (90° closed stirrups)

$$\text{psh},x \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00482813$$

$$\text{Lstir (Length of stirrups along Y)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$\text{psh},y \text{ ((5.4d), TBDY)} = \text{Lstir} * \text{Astir} / (\text{Asec} * s) = 0.00482813$$

$$\text{Lstir (Length of stirrups along X)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$s = 100.00$$

$$\text{fywe} = 694.45$$

$$\text{fce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: cc} = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y1 = 0.00140044$$

$$\text{sh1} = 0.0044814$$

$$\text{ft1} = 466.8167$$

$$\text{fy1} = 389.0139$$

$$\text{su1} = 0.00512$$

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

$$\text{lo/lou,min} = \text{lb/ld} = 0.30$$

$$\text{su1} = 0.4 * \text{esu1_nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fs1} = \text{fs} = 389.0139$$

$$\text{with Es1} = \text{Es} = 200000.00$$

$$y2 = 0.00140044$$

$$\text{sh2} = 0.0044814$$

$$\text{ft2} = 466.8167$$

$$\text{fy2} = 389.0139$$

$$\text{su2} = 0.00512$$

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

$$\text{lo/lou,min} = \text{lb/lb,min} = 0.30$$

$$\text{su2} = 0.4 * \text{esu2_nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fs2} = \text{fs} = 389.0139$$

$$\text{with Es2} = \text{Es} = 200000.00$$

$$yv = 0.00140044$$

$$\text{shv} = 0.0044814$$

$$\text{ftv} = 466.8167$$

$$\text{fyv} = 389.0139$$

$$\text{suv} = 0.00512$$

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

$$\text{lo/lou,min} = \text{lb/ld} = 0.30$$

$$\text{suv} = 0.4 * \text{esuv_nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fsv} = \text{fs} = 389.0139$$

$$\text{with Esv} = \text{Es} = 200000.00$$

$$1 = \text{Asl,ten} / (\text{b} * \text{d}) * (\text{fs1} / \text{fc}) = 0.0292549$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.06704247$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$f_{cc} (5A.2, TBDY) = 35.22334$$

$$c_c (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.03435585$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07873215$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.15879007$$

$$M_u = M_{Rc} (4.14) = 3.2075E+008$$

$$u = s_u (4.1) = 1.0927237E-005$$

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$

$$V_{Col0} = 631439.816$$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} + f * V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$$f_c' = 33.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$M_u = 90.32855$$

$$V_u = 0.14056349$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8933.736$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 593416.693$$

where:

$V_{s1} = 174534.321$ is calculated for section web, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

V_{s1} is multiplied by $Col1 = 1.00$

$$s/d = 0.50$$

$V_{s2} = 418882.372$ is calculated for section flange, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

V_{s2} is multiplied by $Col2 = 1.00$

$$s/d = 0.20833333$$

$$V_f ((11-3)-(11.4), ACI 440) = 365392.00$$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.00$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

f_{fe} ((11-5), ACI 440) = 328.00

$E_f = 82000.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.009$

From (11-11), ACI 440: $V_s + V_f \leq 457936.196$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$

$V_{Col0} = 544688.006$

$k_{nl} = 1$ (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).

$\gamma = 1$ (normal-weight concrete)

$f_c' = 33.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/d = 4.00$

$\mu_u = 330.5627$

$\nu_u = 0.14056349$

$d = 0.8 \cdot h = 480.00$

$N_u = 8933.736$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$

where:

$V_{s1} = 174534.321$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.50$

$V_{s2} = 418882.372$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.20833333$

V_f ((11-3)-(11.4), ACI 440) = 365392.00

$f = 0.95$, 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 $V_f(\theta)$, 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.00$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

f_{fe} ((11-5), ACI 440) = 328.00

$E_f = 82000.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.009$

From (11-11), ACI 440: $V_s + V_f \leq 457936.196$

$b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

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, $M = -155500.631$

Shear Force, $V_2 = 3417.76$

Shear Force, $V_3 = -187.9626$

Axial Force, $F = -9508.222$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl} = 0.00$

-Compression: $A_{slc} = 4737.522$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1900.664$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 2007.478$

Mean Diameter of Tension Reinforcement, $DbL = 17.25$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.03190628$

$u = \gamma + \rho = 0.03190628$

- Calculation of ρ_y -

$$y = (M_y * L_s / 3) / E_{eff} = 0.00190628 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 3.7224E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 827.2955$$

$$\text{From table 10.5, ASCE 41-17: } E_{eff} = \text{factor} * E_c * I_g = 5.3849E+013$$

$$\text{factor} = 0.30$$

$$A_g = 237500.00$$

$$f_c' = 33.00$$

$$N = 9508.222$$

$$E_c * I_g = 1.7950E+014$$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to Annex 7 -

$$y = \text{Min}(y_{ten}, y_{com})$$

$$y_{ten} = 4.4401709E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 311.2112$$

$$d = 558.00$$

$$y = 0.37195426$$

$$A = 0.03417974$$

$$B = 0.02205173$$

$$\text{with } p_t = 0.01362483$$

$$p_c = 0.00594538$$

$$p_v = 0.01439052$$

$$N = 9508.222$$

$$b = 250.00$$

$$" = 0.07706093$$

$$y_{comp} = 1.0794825E-005$$

$$\text{with } f_c' \text{ (12.3, (ACI 440))} = 33.51939$$

$$f_c = 33.00$$

$$f_l = 0.77310341$$

$$b = b_{max} = 600.00$$

$$h = h_{max} = 600.00$$

$$A_g = 237500.00$$

$$g = p_t + p_c + p_v = 0.03396073$$

$$r_c = 40.00$$

$$A_e / A_c = 0.21429949$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.00$$

$$\text{effective strain from (12.5) and (12.12), } e_{fe} = 0.004$$

$$f_u = 0.009$$

$$E_f = 82000.00$$

$$E_c = 26999.444$$

$$y = 0.37099155$$

$$A = 0.03380823$$

$$B = 0.02183272$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio l_b / l_d

Inadequate Lap Length with $l_b / l_d = 0.30$

- Calculation of ρ_p -

From table 10-8: $\rho_p = 0.03$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b / l_d \geq 1$

$$\text{shear control ratio } V_y E / V_{col} O E = 0.73796687$$

$$d = 558.00$$

$$s = 0.00$$

$$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$$

$A_v = 78.53982$, is the area of every stirrup
 $L_{stir} = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction
 The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ 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.

$N_{UD} = 9508.222$

$A_g = 237500.00$

$f_{cE} = 33.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.03396073$

$b = 250.00$

$d = 558.00$

$f_{cE} = 33.00$

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

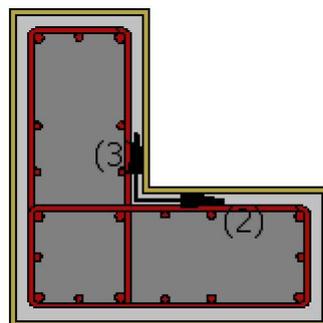
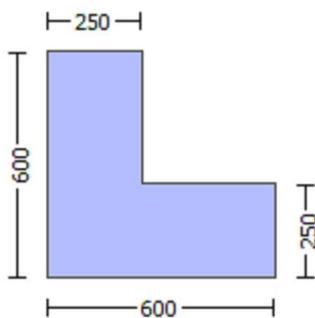
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rclcs

Constant Properties

Knowledge Factor, = 1.00

```

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$ 
New material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$ 
Concrete Elasticity,  $E_c = 26999.444$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE41-17).
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material: Steel Strength,  $f_s = f_{sm} = 555.56$ 
#####
Max Height,  $H_{max} = 600.00$ 
Min Height,  $H_{min} = 250.00$ 
Max Width,  $W_{max} = 600.00$ 
Min Width,  $W_{min} = 250.00$ 
Cover Thickness,  $c = 25.00$ 
Element Length,  $L = 3000.00$ 
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with  $l_o/l_{ou,min} = l_b/l_d = 0.30$ 
FRP Wrapping Data
Type: Carbon
Dry properties (design values)
Thickness,  $t = 1.00$ 
Tensile Strength,  $f_{fu} = 840.00$ 
Tensile Modulus,  $E_f = 82000.00$ 
Elongation,  $e_{fu} = 0.009$ 
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,  $M_a = -407714.86$ 
Shear Force,  $V_a = 187.9626$ 
EDGE -B-
Bending Moment,  $M_b = -155500.631$ 
Shear Force,  $V_b = -187.9626$ 
BOTH EDGES
Axial Force,  $F = -9508.222$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $A_{st} = 0.00$ 
-Compression:  $A_{sc} = 4737.522$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $A_{st,ten} = 1900.664$ 
-Compression:  $A_{sl,com} = 829.3805$ 
-Middle:  $A_{sl,mid} = 2007.478$ 
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 17.25$ 
-----
-----

New component: From table 7-7, ASCE 41_17: Final Shear Capacity  $V_R = 1.0*V_n = 549940.358$ 
 $V_n ((10.3), ASCE 41-17) = knl*V_{CoIO} = 549940.358$ 
 $V_{CoI} = 549940.358$ 
 $knl = 1.00$ 
displacement_ductility_demand = 1.7156631E-005
-----

```

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

fc' = 25.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 155500.631

Vu = 187.9626

d = 0.8*h = 480.00

Nu = 9508.222

Ag = 150000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 534070.751

where:

Vs1 = 376991.118 is calculated for section web, with:

d = 480.00

Av = 157079.633

fy = 500.00

s = 100.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.20833333

Vs2 = 157079.633 is calculated for section flange, with:

d = 200.00

Av = 157079.633

fy = 500.00

s = 100.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.50

Vf ((11-3)-(11.4), ACI 440) = 365392.00

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: $\alpha_1 = b_1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, α_1)|, |Vf(-45, α_1)|), with:

total thickness per orientation, tf1 = NL*t/NoDir = 1.00

dfv = d (figure 11.2, ACI 440) = 557.00

ffe ((11-5), ACI 440) = 328.00

Ef = 82000.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.009

From (11-11), ACI 440: Vs + Vf <= 398582.298

bw = 250.00

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END B -

for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 3.2705420E-008$

$y = (My*Lv/3)/Eleff = 0.00190628$ ((4.29), Biskinis Phd))

My = 3.7224E+008

Ls = M/V (with $Ls > 0.1*L$ and $Ls < 2*L$) = 827.2955

From table 10.5, ASCE 41_17: Eleff = factor*Ec*Ig = 5.3849E+013

factor = 0.30

Ag = 237500.00

fc' = 33.00

N = 9508.222

Ec*Ig = 1.7950E+014

Calculation of Yielding Moment My

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.4401709\text{E-}006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/l_d)^{2/3}) = 311.2112$
 $d = 558.00$
 $y = 0.37195426$
 $A = 0.03417974$
 $B = 0.02205173$
with $p_t = 0.01362483$
 $p_c = 0.00594538$
 $p_v = 0.01439052$
 $N = 9508.222$
 $b = 250.00$
 $" = 0.07706093$
 $y_{\text{comp}} = 1.0794825\text{E-}005$
with f_c^* (12.3, (ACI 440)) = 33.51939
 $f_c = 33.00$
 $f_l = 0.77310341$
 $b = b_{\text{max}} = 600.00$
 $h = h_{\text{max}} = 600.00$
 $A_g = 237500.00$
 $g = p_t + p_c + p_v = 0.03396073$
 $r_c = 40.00$
 $A_e/A_c = 0.21429949$
Effective FRP thickness, $t_f = N L^* t \cdot \text{Cos}(b_1) = 1.00$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.009$
 $E_f = 82000.00$
 $E_c = 26999.444$
 $y = 0.37099155$
 $A = 0.03380823$
 $B = 0.02183272$
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: 3

Integration Section: (b)

Calculation No. 16

column C1, Floor 1

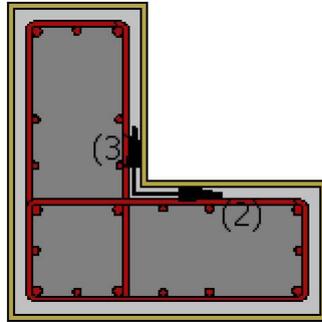
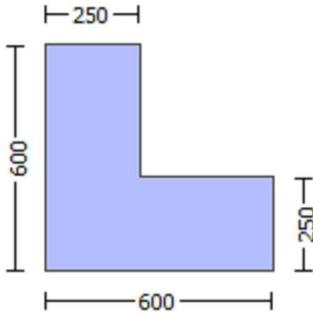
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

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 = 1.06737

Element Length, $L = 3000.00$

Secondary Member

Smooth Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with $l_o/l_{ou,min} = 0.30$

FRP Wrapping Data

Type: Carbon

Dry properties (design values)

Thickness, $t = 1.00$

Tensile Strength, $f_{fu} = 840.00$

Tensile Modulus, $E_f = 82000.00$

Elongation, $e_{fu} = 0.009$

Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, Va = 0.14056349
EDGE -B-
Shear Force, Vb = -0.14056349
BOTH EDGES
Axial Force, F = -8933.736
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 4737.522
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1900.664
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 2007.478

Calculation of Shear Capacity ratio , $V_e/V_r = 0.73796687$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$
with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 6.0294E+008$
 $\mu_{1+} = 6.0294E+008$, 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
 $\mu_{1-} = 3.2075E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 6.0294E+008$
 $\mu_{2+} = 6.0294E+008$, 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
 $\mu_{2-} = 3.2075E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.3372380E-005$

$M_u = 6.0294E+008$

with full section properties:

b = 250.00

d = 558.00

d' = 43.00

v = 0.00194064

N = 8933.736

f_c = 33.00

co (5A.5, TBDY) = 0.002

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01247586$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.01247586$

μ_{we} ((5.4c), TBDY) = $a_{se} * \text{sh}_{,\text{min}} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04207769$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.24098246$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $pf = 2t_f/b_w = 0.008$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$f_y = 0.04207769$

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), $pf = 2t_f/b_w = 0.008$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$R = 40.00$

Effective FRP thickness, $t_f = NL*t*\text{Cos}(b_1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}), 0) = 0.27151783$

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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00482813$

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

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.30$

$su_1 = 0.4*su_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $su_{1,nominal} = 0.08$,

For calculation of $su_{1,nominal}$ 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 $f_{s1} = f_s = 389.0139$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.00140044$
 $sh_2 = 0.0044814$
 $ft_2 = 466.8167$
 $fy_2 = 389.0139$
 $su_2 = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.30$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 389.0139$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00140044$
 $sh_v = 0.0044814$
 $ft_v = 466.8167$
 $fy_v = 389.0139$
 $suv = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsy_v = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsy_v = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 389.0139$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16061358$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07008593$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1696398$

and confined core properties:

$b = 190.00$
 $d = 528.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22334125$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.097458$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23589266$

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

--->
 $su (4.8) = 0.31383738$
 $Mu = MR_c (4.15) = 6.0294E+008$
 $u = su (4.1) = 1.3372380E-005$

 Calculation of ratio l_b/l_d

 Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Mu_1 -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0927237E-005$$

$$\mu = 3.2075E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 42.00$$

$$v = 0.00081005$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$\alpha_{co} (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01247586$$

$$\phi_{cc} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05035379$$

where $\phi_f = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 57233.333$$

$$b_{\text{max}} = 600.00$$

$$h_{\text{max}} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$\phi_{fy} = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 0.00$$

$$b_{\text{max}} = 600.00$$

$$h_{\text{max}} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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).

$$\text{psh}_{, \text{min}} = \text{Min}(\text{psh}_{,x}, \text{psh}_{,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $\text{psh}_{, \text{min}}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\text{psh}_{,x} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} (\text{Length of stirrups along } Y) = 1460.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00482813$$

$$Lstir (\text{Length of stirrups along } X) = 1460.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 237500.00$$

$$s = 100.00$$

$$fywe = 694.45$$

$$fce = 33.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 389.0139$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2, ft2, fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 389.0139$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$$fyv = 389.0139$$

$$suv = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv, ftv, fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0292549$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.06704247$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$fcc (5A.2, TBDY) = 35.22334$$

$$cc (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.03435585$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.07873215$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.15879007$$

$$Mu = MRc (4.14) = 3.2075E+008$$

$$u = su (4.1) = 1.0927237E-005$$

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:

$$u = 1.3372380E-005$$

$$Mu = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$fc = 33.00$$

$$co (5A.5, TBDY) = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.01247586$$

$$w_e ((5.4c), TBDY) = ase * sh, \min * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.05035379$$

where $f = af * pf * ff_e/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff_e = 720.2618$$

$$fy = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff_e = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL * t * \text{Cos}(b1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.27151783$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 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).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00482813$$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00482813$$

$$Lstir \text{ (Length of stirrups along Y)} = 1460.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 237500.00$$

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00482813$$

$$Lstir \text{ (Length of stirrups along X)} = 1460.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$fywe = 694.45$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y1 = 0.00140044$$

$$sh1 = 0.0044814$$

$$ft1 = 466.8167$$

$$fy1 = 389.0139$$

$$su1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.30$$

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 389.0139$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00140044$$

$$sh2 = 0.0044814$$

$$ft2 = 466.8167$$

$$fy2 = 389.0139$$

$$su2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.30$$

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2, ft2, fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 389.0139$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00140044$$

$$shv = 0.0044814$$

$$ftv = 466.8167$$

$f_{yv} = 389.0139$
 $s_{uv} = 0.00512$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,
 considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $e_{suv_nominal}$ and γ_v , sh_v, ft_v, fy_v , it is considered
 characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.
 $\gamma_1, sh_1, ft_1, fy_1$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 389.0139$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16061358$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.07008593$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.1696398$
 and confined core properties:
 $b = 190.00$
 $d = 528.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 35.22334$
 $cc (5A.5, TBDY) = 0.00267374$
 $c = \text{confinement factor} = 1.06737$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.22334125$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.097458$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23589266$
 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
 --->
 $su (4.8) = 0.31383738$
 $Mu = MR_c (4.15) = 6.0294E+008$
 $u = su (4.1) = 1.3372380E-005$

 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:

$u = 1.0927237E-005$
 $Mu = 3.2075E+008$

 with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 42.00$
 $v = 0.00081005$
 $N = 8933.736$
 $f_c = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01247586$
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$
 where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \cos(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$$

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).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/d = 0.30$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 389.0139$

with $Es1 = Es = 200000.00$

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{min} = lb/lb_{min} = 0.30$

$su2 = 0.4 \cdot esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 389.0139$

with $Es2 = Es = 200000.00$

$yv = 0.00140044$

$shv = 0.0044814$

$ftv = 466.8167$

$fyv = 389.0139$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{min} = lb/ld = 0.30$

$suv = 0.4 \cdot esuv_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 389.0139$

with $Es_v = Es = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.0292549$

2 = $Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.06704247$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.07081015$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 12.00$

f_{cc} (5A.2, TBDY) = 35.22334

cc (5A.5, TBDY) = 0.00267374

c = confinement factor = 1.06737

1 = $Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.03435585$

2 = $Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.07873215$

v = $Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.08315676$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.15879007

$Mu = MRc$ (4.14) = 3.2075E+008

$u = su$ (4.1) = 1.0927237E-005

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$

$V_{r1} = V_{Co1} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Co10}$

$V_{Co10} = 631439.816$

$k_{nl} = 1$ (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)

$f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 90.31778$

$\nu_u = 0.14056349$

$d = 0.8 * h = 480.00$

$N_u = 8933.736$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$

where:

$V_{s1} = 418882.372$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.20833333$

$V_{s2} = 174534.321$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.50$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 365392.00$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.00$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

$f_{fe} ((11-5), \text{ACI } 440) = 328.00$

$E_f = 82000.00$

$f_{e} = 0.004$, from (11.6a), ACI 440

with $f_u = 0.009$

From (11-11), ACI 440: $V_s + V_f \leq 457936.196$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 544688.006$

$V_{r2} = V_{Co2} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Co10}$

$V_{Co10} = 544688.006$

$k_{nl} = 1$ (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)

$f_c' = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 330.5734$

$\nu_u = 0.14056349$

$d = 0.8 \cdot h = 480.00$
 $Nu = 8933.736$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 593416.693$
 where:
 $Vs1 = 418882.372$ is calculated for section web, with:
 $d = 480.00$
 $Av = 157079.633$
 $fy = 555.56$
 $s = 100.00$
 $Vs1$ is multiplied by $Col1 = 1.00$
 $s/d = 0.20833333$
 $Vs2 = 174534.321$ is calculated for section flange, with:
 $d = 200.00$
 $Av = 157079.633$
 $fy = 555.56$
 $s = 100.00$
 $Vs2$ is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 Vf ((11-3)-(11.4), ACI 440) = 365392.00
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\alpha, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\alpha = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \alpha)|, |Vf(-45, \alpha)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.00$
 $dfv = d$ (figure 11.2, ACI 440) = 557.00
 ffe ((11-5), ACI 440) = 328.00
 $Ef = 82000.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.009$
 From (11-11), ACI 440: $Vs + Vf \leq 457936.196$
 $bw = 250.00$

 End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rclcs

Constant Properties

 Knowledge Factor, $\phi = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$
 #####
 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 = 1.06737
Element Length, $L = 3000.00$
Secondary Member
Smooth Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with $l_o/l_{o,min} = 0.30$
FRP Wrapping Data
Type: Carbon
Dry properties (design values)
Thickness, $t = 1.00$
Tensile Strength, $f_{fu} = 840.00$
Tensile Modulus, $E_f = 82000.00$
Elongation, $e_{fu} = 0.009$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 0.14056349$
EDGE -B-
Shear Force, $V_b = -0.14056349$
BOTH EDGES
Axial Force, $F = -8933.736$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 4737.522$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1900.664$
-Compression: $As_{c,com} = 829.3805$
-Middle: $As_{c,mid} = 2007.478$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.73796687$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 401961.704$
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 6.0294E+008$
 $Mu_{1+} = 6.0294E+008$, 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
 $Mu_{1-} = 3.2075E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 6.0294E+008$
 $Mu_{2+} = 6.0294E+008$, 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
 $Mu_{2-} = 3.2075E+008$, 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:
 $\phi_u = 1.3372380E-005$
 $Mu = 6.0294E+008$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01247586$$

$$\text{we ((5.4c), TBDY) } = a_s e^* s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $p_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 237500.00$$

$$s = 100.00$$

$$f_{ywe} = 694.45$$

$$f_{ce} = 33.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00267374$
 $c = \text{confinement factor} = 1.06737$

$y1 = 0.00140044$

$sh1 = 0.0044814$

$ft1 = 466.8167$

$fy1 = 389.0139$

$su1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou, \min = lb/d = 0.30$

$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 389.0139$

with $Es1 = Es = 200000.00$

$y2 = 0.00140044$

$sh2 = 0.0044814$

$ft2 = 466.8167$

$fy2 = 389.0139$

$su2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou, \min = lb/lb, \min = 0.30$

$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 389.0139$

with $Es2 = Es = 200000.00$

$yv = 0.00140044$

$shv = 0.0044814$

$ftv = 466.8167$

$fyv = 389.0139$

$suv = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou, \min = lb/d = 0.30$

$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fsv = fs = 389.0139$

with $Esv = Es = 200000.00$

$1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.16061358$

$2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.07008593$

$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.1696398$

and confined core properties:

$b = 190.00$

$d = 528.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 35.22334$

$cc (5A.5, TBDY) = 0.00267374$

$c = \text{confinement factor} = 1.06737$

$1 = Asl, \text{ten} / (b * d) * (fs1 / fc) = 0.22334125$

$2 = Asl, \text{com} / (b * d) * (fs2 / fc) = 0.097458$

$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.23589266$

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

--->

$$s_u(4.8) = 0.31383738$$

$$M_u = M_{Rc}(4.15) = 6.0294E+008$$

$$u = s_u(4.1) = 1.3372380E-005$$

Calculation of ratio I_b/I_d

Inadequate Lap Length with $I_b/I_d = 0.30$

Calculation of M_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0927237E-005$$

$$M_u = 3.2075E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 42.00$$

$$v = 0.00081005$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$\alpha(5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \alpha_c = 0.01247586$$

$$\alpha_{we} \text{ ((5.4c), TBDY) } = \alpha_{se} * \text{sh}_{,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

where $f = \alpha^* p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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.

$A_{conf,max} = 169100.00$ 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).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00482813$

Expression ((5.4d), TBDY) for psh_{min} has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 psh_x ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00482813$

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

 $s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

$c = \text{confinement factor} = 1.06737$

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su_1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$fy_2 = 389.0139$

$su_2 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30$

$su_2 = 0.4 * esu2_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 389.0139$

with $Es_2 = Es = 200000.00$

$y_v = 0.00140044$

$sh_v = 0.0044814$

$ft_v = 466.8167$

$fy_v = 389.0139$

$su_v = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv , shv,ftv,fyv , it is considered characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY.

$y1$, $sh1,ft1,fy1$, are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.0292549$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.06704247$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$fcc (5A.2, TBDY) = 35.22334$$

$$cc (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.03435585$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.07873215$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.08315676$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.15879007$$

$$Mu = MRc (4.14) = 3.2075E+008$$

$$u = su (4.1) = 1.0927237E-005$$

Calculation of ratio lb/ld

Inadequate Lap Length with $lb/ld = 0.30$

Calculation of $Mu2+$

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.3372380E-005$$

$$Mu = 6.0294E+008$$

with full section properties:

$$b = 250.00$$

$$d = 558.00$$

$$d' = 43.00$$

$$v = 0.00194064$$

$$N = 8933.736$$

$$fc = 33.00$$

$$co (5A.5, TBDY) = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.01247586$$

$$we ((5.4c), TBDY) = ase * sh,min * fywe / fce + \text{Min}(fx, fy) = 0.05035379$$

where $f = af * pf * ffe / fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$$af = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008$$

$$bw = 250.00$$

effective stress from (A.35), $f_{f,e} = 720.2618$

$f_y = 0.04207769$

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), $p_f = 2t_f/b_w = 0.008$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 720.2618$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.00$

$f_{u,f} = 840.00$

$E_f = 82000.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.27151783$

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).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$

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

$s = 100.00$

$f_{ywe} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00267374$

c = confinement factor = 1.06737

$y_1 = 0.00140044$

$sh_1 = 0.0044814$

$ft_1 = 466.8167$

$fy_1 = 389.0139$

$su_1 = 0.00512$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.30$

$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 389.0139$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00140044$

$sh_2 = 0.0044814$

$ft_2 = 466.8167$

$$f_y2 = 389.0139$$

$$s_u2 = 0.00512$$

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

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 0.30$$

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,

For calculation of $e_{su2,nominal}$ and y_2, sh_2, ft_2, f_y2 , it is considered
characteristic value $f_{sy2} = f_s2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_y1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 389.0139$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$f_{y_v} = 389.0139$$

$$s_{u_v} = 0.00512$$

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

$$l_o/l_{o,u,min} = l_b/l_d = 0.30$$

$$s_{u_v} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, f_{y_v} , it is considered
characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{sv} = f_s = 389.0139$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.16061358$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.07008593$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.1696398$$

and confined core properties:

$$b = 190.00$$

$$d = 528.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 35.22334$$

$$cc (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.22334125$$

$$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.097458$$

$$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.23589266$$

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

--->

$$s_u (4.8) = 0.31383738$$

$$M_u = M_{Rc} (4.15) = 6.0294E+008$$

$$u = s_u (4.1) = 1.3372380E-005$$

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 u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0927237E-005$$

$$\mu = 3.2075E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 42.00$$

$$v = 0.00081005$$

$$N = 8933.736$$

$$f_c = 33.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01247586$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \alpha_c = 0.01247586$$

$$\omega_e ((5.4c), \text{TBDY}) = \alpha_c^* * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05035379$$

where $f = \alpha_c^* * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$f_y = 0.04207769$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 720.2618$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.00$$

$$f_{u,f} = 840.00$$

$$E_f = 82000.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.27151783$$

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)

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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).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00482813$$

Expression ((5.4d), TBDY) for $p_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} ((5.4d), \text{TBDY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} (\text{Length of stirrups along } Y) = 1460.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$p_{sh,y} ((5.4d), \text{TBDY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00482813$$

$$L_{\text{stir}} (\text{Length of stirrups along } X) = 1460.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$s = 100.00$$

$$fy_{we} = 694.45$$

$$f_{ce} = 33.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00267374$

$$c = \text{confinement factor} = 1.06737$$

$$y_1 = 0.00140044$$

$$sh_1 = 0.0044814$$

$$ft_1 = 466.8167$$

$$fy_1 = 389.0139$$

$$su_1 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 0.30$$

$$su_1 = 0.4 * esu_{1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{1_nominal} = 0.08$,

For calculation of $esu_{1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 389.0139$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00140044$$

$$sh_2 = 0.0044814$$

$$ft_2 = 466.8167$$

$$fy_2 = 389.0139$$

$$su_2 = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/lb, \min = 0.30$$

$$su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2_nominal} = 0.08$,

For calculation of $esu_{2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 389.0139$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.00140044$$

$$sh_v = 0.0044814$$

$$ft_v = 466.8167$$

$$fy_v = 389.0139$$

$$su_v = 0.00512$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 0.30$$

$$su_v = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_nominal$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 389.0139$$

$$\text{with } Es_v = Es = 200000.00$$

$$1 = Asl, \text{ten}/(b*d) * (fs_1/fc) = 0.0292549$$

$$2 = Asl, \text{com}/(b*d) * (fs_2/fc) = 0.06704247$$

$$v = Asl, \text{mid}/(b*d) * (fsv/fc) = 0.07081015$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 12.00$$

$$fcc (5A.2, TBDY) = 35.22334$$

$$cc (5A.5, TBDY) = 0.00267374$$

$$c = \text{confinement factor} = 1.06737$$

$$1 = Asl, \text{ten}/(b*d) * (fs_1/fc) = 0.03435585$$

$$2 = Asl, \text{com}/(b*d) * (fs_2/fc) = 0.07873215$$

$$v = Asl, \text{mid}/(b*d) * (fsv/fc) = 0.08315676$$

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) = 0.15879007
 $M_u = MR_c$ (4.14) = 3.2075E+008
 $u = s_u$ (4.1) = 1.0927237E-005

Calculation of ratio l_b/l_d

Inadequate Lap Length with $l_b/l_d = 0.30$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 544688.006$

Calculation of Shear Strength at edge 1, $V_{r1} = 631439.816$
 $V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l V_{Col0}$
 $V_{Col0} = 631439.816$
 $k_n l = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+ f} V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

 $= 1$ (normal-weight concrete)
 $f_c' = 33.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 90.32855$
 $V_u = 0.14056349$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8933.736$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 593416.693$
where:
 $V_{s1} = 174534.321$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 418882.372$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.20833333$
 V_f ((11-3)-(11.4), ACI 440) = 365392.00
 $f = 0.95$, 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 $V_f(\alpha)$, is implemented for every different fiber orientation α_i ,
as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\alpha = 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$, with:
total thickness per orientation, $t_f = N_L \cdot t / N_{Dir} = 1.00$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 f_{fe} ((11-5), ACI 440) = 328.00
 $E_f = 82000.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.009$
From (11-11), ACI 440: $V_s + V_f \leq 457936.196$

bw = 250.00

Calculation of Shear Strength at edge 2, Vr2 = 544688.006
Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0
VCol0 = 544688.006
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' = 33.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 330.5627
Vu = 0.14056349
d = 0.8*h = 480.00
Nu = 8933.736
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 593416.693

where:

Vs1 = 174534.321 is calculated for section web, with:

d = 200.00
Av = 157079.633
fy = 555.56
s = 100.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.50

Vs2 = 418882.372 is calculated for section flange, with:

d = 480.00
Av = 157079.633
fy = 555.56
s = 100.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.20833333

Vf ((11-3)-(11.4), ACI 440) = 365392.00

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc)\sin\alpha$ which is more a generalised expression,

where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(α), is implemented for every different fiber orientation ai, as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, α)|, |Vf(-45, α)|), with:

total thickness per orientation, tf1 = NL*t/NoDir = 1.00

dfv = d (figure 11.2, ACI 440) = 557.00

ffe ((11-5), ACI 440) = 328.00

Ef = 82000.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.009

From (11-11), ACI 440: Vs + Vf <= 457936.196

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\phi = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 Max Height, $H_{max} = 600.00$
 Min Height, $H_{min} = 250.00$
 Max Width, $W_{max} = 600.00$
 Min Width, $W_{min} = 250.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Smooth Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Inadequate Lap Length with $l_b/l_d = 0.30$
 FRP Wrapping Data
 Type: Carbon
 Dry properties (design values)
 Thickness, $t = 1.00$
 Tensile Strength, $f_{fu} = 840.00$
 Tensile Modulus, $E_f = 82000.00$
 Elongation, $e_{fu} = 0.009$
 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, $M = 183142.393$
 Shear Force, $V_2 = 3417.76$
 Shear Force, $V_3 = -187.9626$
 Axial Force, $F = -9508.222$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl} = 0.00$
 -Compression: $A_{sl,c} = 4737.522$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten} = 1900.664$
 -Compression: $A_{sl,com} = 829.3805$
 -Middle: $A_{sl,mid} = 2007.478$
 Mean Diameter of Tension Reinforcement, $D_bL = 17.25$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^* u = 0.03069127$
 $u = y + p = 0.03069127$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00069127$ ((4.29), Biskinis Phd)
 $M_y = 3.7224E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 5.3849E+013$
 factor = 0.30
 $A_g = 237500.00$
 $f_c' = 33.00$
 $N = 9508.222$
 $E_c * I_g = 1.7950E+014$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.4401709\text{E-}006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 311.2112$
 $d = 558.00$
 $y = 0.37195426$
 $A = 0.03417974$
 $B = 0.02205173$
with $pt = 0.01362483$
 $pc = 0.00594538$
 $pv = 0.01439052$
 $N = 9508.222$
 $b = 250.00$
 $\rho = 0.07706093$
 $y_{\text{comp}} = 1.0794825\text{E-}005$
with $f_c^* (12.3, (ACI 440)) = 33.51939$
 $f_l = 33.00$
 $fl = 0.77310341$
 $b = b_{\text{max}} = 600.00$
 $h = h_{\text{max}} = 600.00$
 $Ag = 237500.00$
 $g = pt + pc + pv = 0.03396073$
 $rc = 40.00$
 $Ae/Ac = 0.21429949$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b1) = 1.00$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.009$
 $E_f = 82000.00$
 $E_c = 26999.444$
 $y = 0.37099155$
 $A = 0.03380823$
 $B = 0.02183272$
with $E_s = 200000.00$

Calculation of ratio l_b/d

Inadequate Lap Length with $l_b/d = 0.30$

- Calculation of ρ_p -

From table 10-8: $\rho_p = 0.03$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$

shear control ratio $V_y E / V_{CoI} E = 0.73796687$

$d = 558.00$

$s = 0.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = A_v \cdot L_{\text{stir}} / (A_g \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{\text{stir}} = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$NUD = 9508.222$

$Ag = 237500.00$

$f_c E = 33.00$

$f_y E = f_{yE} = 0.00$

$\rho_l = \text{Area}_{\text{Tot_Long_Rein}} / (b \cdot d) = 0.03396073$

$b = 250.00$

$d = 558.00$

$f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
At local axis: 3
Integration Section: (b)
