

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

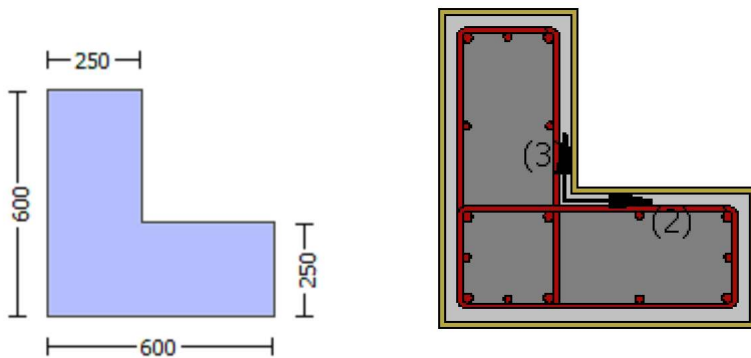
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VR_d

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$

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

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

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$
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 Note: Especially for the calculation of γ for displacement ductility demand,
 the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
 Deformation-Controlled Action (Table C7-1, ASCE41-17).
 Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material: Steel Strength, $f_s = f_{sm} = 444.44$
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 Max Height, $H_{max} = 600.00$
 Min Height, $H_{min} = 250.00$
 Max Width, $W_{max} = 600.00$
 Min Width, $W_{min} = 250.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -1.2946E+007$
 Shear Force, $V_a = -4259.045$
 EDGE -B-
 Bending Moment, $M_b = 164093.879$
 Shear Force, $V_b = 4259.045$
 BOTH EDGES
 Axial Force, $F = -9662.362$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 4121.77$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{l,ten} = 1746.726$
 -Compression: $As_{l,com} = 829.3805$
 -Middle: $As_{l,mid} = 1545.664$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $VR = *V_n = 292301.036$
 $V_n ((10.3), ASCE 41-17) = knl * V_{Col} = 379611.735$
 $V_{Col} = 379611.735$
 $knl = 1.00$
 $displacement_ductility_demand = 0.01786943$

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

$= 1$ (normal-weight concrete)
 $f'_c = 16.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$

$\mu = 1.2946 \times 10^7$
 $V_u = 4259.045$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9662.362$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 284837.734$
 where:
 $V_{s1} = 83775.804$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 150.00$
 V_{s1} is multiplied by $\text{Col1} = 1.00$
 $s/d = 0.75$
 $V_{s2} = 201061.93$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 150.00$
 V_{s2} is multiplied by $\text{Col2} = 1.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot \alpha) \sin \alpha$ which is more a generalised expression,
 where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\alpha_1 = \alpha_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 318865.838$
 $b_w = 250.00$

displacement_ductility_demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 0.00012672$
 $y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.0070913$ ((4.29), Biskinis Phd))
 $M_y = 2.9341 \times 10^8$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3039.546
 From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 4.1921 \times 10^{13}$
 $\text{factor} = 0.30$
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9662.362$
 $E_c \cdot I_g = 1.3974 \times 10^{14}$

Calculation of Yielding Moment M_y

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

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.0518245 \times 10^{-6}$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 277.9106$
 $d = 557.00$

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

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Calculation of ratio lb/l_d

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

l_b = 300.00

l_d = 847.9072

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

= 1

db = 18.00

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

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 2.61799

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

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

s = 150.00

n = 16.00

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

At local axis: 2

Integration Section: (a)

Calculation No. 2

column C1, Floor 1

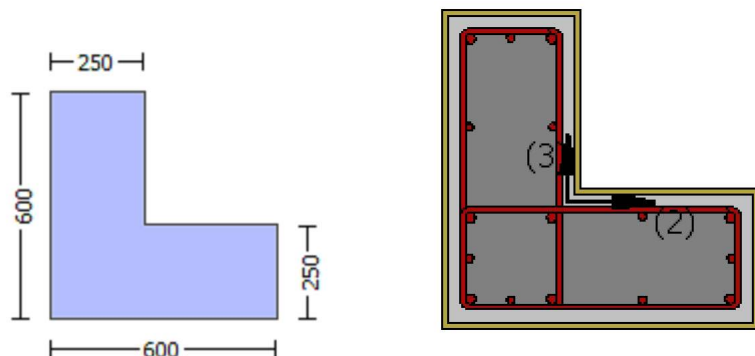
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

Edge: Start

Local Axis: (2)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

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Note: Especially for the calculation of moment strengths,

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

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

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Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, Va = 0.00016213
EDGE -B-
Shear Force, Vb = -0.00016213
BOTH EDGES
Axial Force, F = -8883.864
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 4121.77
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1746.726
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 1545.664

Calculation of Shear Capacity ratio , $V_e/V_r = 0.62612363$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 3.9843\text{E}+008$
 $\mu_{u1+} = 3.9843\text{E}+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 2.1970\text{E}+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 3.9843\text{E}+008$
 $\mu_{u2+} = 3.9843\text{E}+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $\mu_{u2-} = 2.1970\text{E}+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

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

$$\mu_u = 1.1848408\text{E}-005$$

$$\mu_u = 3.9843\text{E}+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, c_o) = 0.0144353$$

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

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

$$w_e((5.4c), \text{TB DY}) = a_s e^* s_{h, \min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$b_{max} = 600.00$

$h_{max} = 600.00$

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

$b_w = 250.00$

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

$f_y = 0.06888919$

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

$a_f = 0.24098246$

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

$b_{max} = 600.00$

$h_{max} = 600.00$

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

$b_w = 250.00$

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

$R = 40.00$

Effective FRP thickness, $t_f = N_L \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

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

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

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

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

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

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

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

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

c = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

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

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

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

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

For calculation of $esu_1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = f_s/1.2$, from table 5.1, TBDY.

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

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with fs1 = fs = 299.3701
with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.28304984
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE41-17.
with fs2 = fs = 299.3701
with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 299.3701
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.32281672
Mu = MRc (4.15) = 3.9843E+008
u = su (4.1) = 1.1848408E-005

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Calculation of ratio lb/lb

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Lap Length: lb/lb = 0.28304984
lb = 300.00
lb = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

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

Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 9.6917274E-006$
 $\mu_1 = 2.1970E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$
 $fc = 20.00$
 $\alpha_1(5A.5, \text{TB DY}) = 0.002$
Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, \mu_c) = 0.0144353$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TB DY: $\mu = 0.0144353$
 μ_c ((5.4c), TB DY) = $\alpha_1 * \mu_{c0} / f_{c0} + \text{Min}(f_x, f_y) = 0.07473805$
where $f = \alpha_1 * \mu_{c0} / f_{c0}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

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

$$\alpha_1 = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

From EC8 A.4.4.3(6), $\mu_{c0} = 2t_f/b_w = 0.008128$

$$b_w = 250.00$$

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

$$f_y = 0.06888919$$

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

$$\alpha_1 = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

From EC8 A.4.4.3(6), $\mu_{c0} = 2t_f/b_w = 0.008128$

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$\mu_{f,e} = 0.015$$

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

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

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

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

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

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

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

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

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

$y1 = 0.00124738$

$sh1 = 0.00431097$

$ft1 = 359.2441$

$fy1 = 299.3701$

$su1 = 0.00446911$

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

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

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

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

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

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

with $fs1 = fs = 299.3701$

with $Es1 = Es = 200000.00$

$y2 = 0.00124738$

$sh2 = 0.00431097$

$ft2 = 359.2441$

$fy2 = 299.3701$

$su2 = 0.00446911$

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

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

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

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

For calculation of $esu2_{nominal}$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

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

with $fs2 = fs = 299.3701$

with $Es2 = Es = 200000.00$

$yv = 0.00124738$

$shv = 0.00431097$

$ftv = 359.2441$

$fyv = 299.3701$

$suv = 0.00446911$

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

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

$\text{suv} = 0.4 \cdot \text{esuv_nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $\text{esuv_nominal} = 0.08$,
 considering characteristic value $\text{fsyv} = \text{fsv}/1.2$, from table 5.1, TBDY
 For calculation of esuv_nominal and yv , shv , ftv , fyv , it is considered
 characteristic value $\text{fsyv} = \text{fsv}/1.2$, from table 5.1, TBDY.
 y1 , sh1 , ft1 , fy1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE41-17.
 with $\text{fsv} = \text{fs} = 299.3701$
 with $\text{Esv} = \text{Es} = 200000.00$
 $1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.03714718$
 $2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.0782342$
 $v = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.06922883$

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $\text{fcc} (5A.2, \text{TBDY}) = 21.96205$
 $\text{cc} (5A.5, \text{TBDY}) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.04362424$
 $2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.09187529$
 $v = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.08129972$

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

--->
 $v < \text{vs,y2}$ - LHS eq.(4.5) is satisfied
 ---->
 $\text{su} (4.9) = 0.17212448$
 $\text{Mu} = \text{MRc} (4.14) = 2.1970\text{E}+008$
 $u = \text{su} (4.1) = 9.6917274\text{E}-006$

Calculation of ratio lb/ld

Lap Length: $\text{lb}/\text{ld} = 0.28304984$
 $\text{lb} = 300.00$
 $\text{ld} = 1059.884$
 Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $\text{db} = 18.00$
 Mean strength value of all re-bars: $\text{fy} = 555.55$
 $\text{fc}' = 20.00$, but $\text{fc}'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $\text{cb} = 25.00$
 $\text{Ktr} = 2.61799$
 $\text{Atr} = \text{Min}(\text{Atr}_x, \text{Atr}_y) = 157.0796$
 where Atr_x , Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.1848408\text{E}-005$
 $\text{Mu} = 3.9843\text{E}+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$

$$f_c = 20.00$$

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

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

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

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

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

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

```

fy1 = 299.3701
su1 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 0.28304984
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fs1 = fs = 299.3701
    with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
    c = confinement factor = 1.0981
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
    2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
    v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is not satisfied
---->
v < vs,c - RHS eq.(4.5) is satisfied
---->
su (4.8) = 0.32281672

```

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

Calculation of ratio l_b/l_d

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

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

$$\begin{aligned} &= 1 \\ d_b &= 18.00 \\ \text{Mean strength value of all re-bars: } f_y &= 555.55 \\ f_c' &= 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)} \\ t &= 1.00 \\ s &= 0.80 \\ e &= 1.00 \\ c_b &= 25.00 \\ K_{tr} &= 2.61799 \\ A_{tr} &= \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796 \\ &\text{where } A_{tr_x}, A_{tr_y} \text{ are the sum of the area of all stirrup legs along X and Y loxal axis} \\ s &= 150.00 \\ n &= 16.00 \end{aligned}$$

Calculation of μ_2 -

$$\begin{aligned} \text{Calculation of ultimate curvature } u &\text{ according to 4.1, Biskinis/Fardis 2013:} \\ u &= 9.6917274E-006 \\ \mu &= 2.1970E+008 \end{aligned}$$

with full section properties:

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

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

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

$R = 40.00$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$
 The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 $A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.
 $A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00321875$
 Expression ((5.4d), TBDY) for $psh_{,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

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

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

$s = 150.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
 From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $y_1 = 0.00124738$
 $sh_1 = 0.00431097$
 $ft_1 = 359.2441$
 $fy_1 = 299.3701$
 $su_1 = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lo_{,min} = lb/l_d = 0.28304984$
 $su_1 = 0.4 \cdot esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,
 For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 299.3701$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.00124738$
 $sh_2 = 0.00431097$
 $ft_2 = 359.2441$
 $fy_2 = 299.3701$
 $su_2 = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lo_{,min} = lb/l_{b,min} = 0.28304984$
 $su_2 = 0.4 \cdot esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

```

with fs2 = fs = 299.3701
with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 299.3701
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
and confined core properties:
b = 540.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.17212448
Mu = MRc (4.14) = 2.1970E+008
u = su (4.1) = 9.6917274E-006

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00

```

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 424229.688

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

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

$V_{Col0} = 424229.688$

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

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

$= 1$ (normal-weight concrete)

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

$M/Vd = 4.00$

$\mu_u = 47.24078$

$\nu_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

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

where:

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

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

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

$s/d = 0.3125$

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

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

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

$s/d = 0.75$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

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

$b_w = 250.00$

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

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

$V_{Col0} = 424229.688$

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

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

$= 1$ (normal-weight concrete)

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

$M/Vd = 4.00$

$\mu_u = 47.24081$

$\nu_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

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

where:

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

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

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

$s/d = 0.3125$

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

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

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

$s/d = 0.75$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

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

$bw = 250.00$

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

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

Constant Properties

Knowledge Factor, $\phi = 0.77$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length, $L = 3000.00$

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

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 0.00016213$
EDGE -B-
Shear Force, $V_b = -0.00016213$
BOTH EDGES
Axial Force, $F = -8883.864$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 4121.77$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1746.726$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.62612363$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.9843E+008$
 $\mu_{u1+} = 3.9843E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 2.1970E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.9843E+008$
 $\mu_{u2+} = 3.9843E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u2-} = 2.1970E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.1848408E-005$
 $\mu_u = 3.9843E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

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

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

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

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

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

$$fx = 0.06888919$$

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

$$af = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$bw = 250.00$$

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

$$fy = 0.06888919$$

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

$$af = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

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

$$bw = 250.00$$

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

$$R = 40.00$$

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

$$fu_f = 1055.00$$

$$Ef = 64828.00$$

$$u_f = 0.015$$

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

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$s = 150.00$$

$$fy_{we} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y1 = 0.00124738$$

```

sh1 = 0.00431097
ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.28304984
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fs1 = fs = 299.3701
    with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
    c = confinement factor = 1.0981
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
    2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
    v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied

```

--->

$$su(4.8) = 0.32281672$$

$$\mu = MRc(4.15) = 3.9843E+008$$

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

Calculation of ratio l_b/l_d

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

$$l_b = 300.00$$

$$l_d = 1059.884$$

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

$$= 1$$

$$d_b = 18.00$$

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

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

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

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

$$s = 150.00$$

$$n = 16.00$$

Calculation of μ_1 -

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

$$u = 9.6917274E-006$$

$$\mu = 2.1970E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \max(c_u, c_c) = 0.0144353$$

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

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

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

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

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

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

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

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

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

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

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

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

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

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

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

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

s = 150.00

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

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

c = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

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

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

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

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

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

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

with $fs_1 = fs = 299.3701$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

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

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

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

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

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

characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 299.3701$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00124738$
 $sh_v = 0.00431097$
 $ft_v = 359.2441$
 $fy_v = 299.3701$
 $suv = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.28304984$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$
 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.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 299.3701$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03714718$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0782342$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06922883$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04362424$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09187529$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08129972$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17212448$
 $Mu = MR_c (4.14) = 2.1970E+008$
 $u = su (4.1) = 9.6917274E-006$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Mu_{2+}

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

$$\phi_u = 1.1848408E-005$$

$$\mu = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$\nu = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_{cu}: \phi_{cu} = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.0144353$$

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

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

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

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

$$\phi_{fx} = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$\phi_{fy} = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$s = 150.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

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

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

$$y1 = 0.00124738$$

$$sh1 = 0.00431097$$

$$ft1 = 359.2441$$

$$fy1 = 299.3701$$

$$su1 = 0.00446911$$

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

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

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

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

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

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

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

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

$$y2 = 0.00124738$$

$$sh2 = 0.00431097$$

$$ft2 = 359.2441$$

$$fy2 = 299.3701$$

$$su2 = 0.00446911$$

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

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

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

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

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

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

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

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

$$yv = 0.00124738$$

$$shv = 0.00431097$$

$$ftv = 359.2441$$

$$fyv = 299.3701$$

$$suv = 0.00446911$$

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

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

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

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

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

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

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

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

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

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

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

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

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc \text{ (5A.2, TBDY)} = 21.96205$$

```

cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.32281672
Mu = MRc (4.15) = 3.9843E+008
u = su (4.1) = 1.1848408E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00

```

Calculation of Mu2-

```

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 9.6917274E-006
Mu = 2.1970E+008

```

with full section properties:

```

b = 600.00
d = 557.00
d' = 43.00
v = 0.00132912
N = 8883.864
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0144353
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0144353
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.07473805
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
fx = 0.06888919
Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)
af = 0.24098246
with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 57233.333
bmax = 600.00
hmax = 600.00

```

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $ff,e = 703.4155$

$fy = 0.06888919$

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

$af = 0.24098246$

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

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

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

$R = 40.00$

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

$fu,f = 1055.00$

$Ef = 64828.00$

$u,f = 0.015$

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

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

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

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

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

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

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

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$fywe = 555.55$

$fce = 20.00$

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

c = confinement factor = 1.0981

$y1 = 0.00124738$

$sh1 = 0.00431097$

$ft1 = 359.2441$

$fy1 = 299.3701$

$su1 = 0.00446911$

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

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

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

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

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

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

with $fs1 = fs = 299.3701$

with $Es1 = Es = 200000.00$

$y2 = 0.00124738$

```

sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/lb = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
and confined core properties:
b = 540.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.17212448
Mu = MRc (4.14) = 2.1970E+008
u = su (4.1) = 9.6917274E-006

```

Calculation of ratio lb/lb

```

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

```

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

Calculation of Shear Strength $Vr = \text{Min}(Vr1, Vr2) = 424229.688$

Calculation of Shear Strength at edge 1, $Vr1 = 424229.688$
 $Vr1 = VCol \text{ ((10.3), ASCE 41-17)} = knl * VCol0$
 $VCol0 = 424229.688$
 $knl = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 47.23669$
 $Vu = 0.00016213$
 $d = 0.8 * h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 316483.206$
 where:
 $Vs1 = 93083.296$ is calculated for section web, with:
 $d = 200.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 150.00$
 $Vs1$ is multiplied by $Col1 = 1.00$
 $s/d = 0.75$
 $Vs2 = 223399.91$ is calculated for section flange, with:
 $d = 480.00$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 150.00$
 $Vs2$ is multiplied by $Col2 = 1.00$
 $s/d = 0.3125$
 $Vf \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc) \sin \alpha$ which is more a generalised expression,
 where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\alpha, \theta)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, \theta)|)$, with:
 total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 557.00
 $ffe \text{ ((11-5), ACI 440)} = 259.312$
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 356502.845$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $Vr2 = 424229.688$
 $Vr2 = VCol \text{ ((10.3), ASCE 41-17)} = knl * VCol0$
 $VCol0 = 424229.688$

knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

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

M/Vd = 4.00

Mu = 47.23667

Vu = 0.00016213

d = 0.8*h = 480.00

Nu = 8883.864

Ag = 150000.00

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

where:

Vs1 = 93083.296 is calculated for section web, with:

d = 200.00

Av = 157079.633

fy = 444.44

s = 150.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.75

Vs2 = 223399.91 is calculated for section flange, with:

d = 480.00

Av = 157079.633

fy = 444.44

s = 150.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.3125

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

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

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

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

Ef = 64828.00

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

with fu = 0.01

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

bw = 250.00

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

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

Integration Section: (a)

Section Type: rdc

Constant Properties

Knowledge Factor, $\phi = 0.77$

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

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

Consequently:

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

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

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

Stepwise Properties

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

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = \frac{u}{p} = 0.00388691$
 $u = y + p = 0.00504794$

- Calculation of y -

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

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -


```

y = Min( y_ten, y_com)
y_ten = 4.0518245E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^ 2/3) = 277.9106
d = 557.00
y = 0.3842998
A = 0.02984946
B = 0.0192317
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9662.362
b = 250.00
" = 0.07719928
y_comp = 8.1947240E-006
with fc* (12.3, (ACI 440)) = 20.42407
fc = 20.00
fl = 0.62098351
b = bmax = 600.00
h = hmax = 600.00
Ag = 237500.00
g = pt + pc + pv = 0.02959978
rc = 40.00
Ae/Ac = 0.21783041
Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 21019.039
y = 0.38318842
A = 0.02940142
B = 0.01898202
with Es = 200000.00

```

Calculation of ratio lb/d

```

Lap Length: ld/d,min = 0.3538123
lb = 300.00
ld = 847.9072
Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 444.44
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00

```

- Calculation of p -

From table 10-8: p = 0.00

with:

- Columns not controlled by inadequate development or splicing along the clear height because lb/d >= 1

shear control ratio $V_yE/V_{ColOE} = 0.62612363$

d = 557.00

s = 0.00

$t = A_v/(b_w*s) + 2*tf/b_w*(ffe/fs) = A_v*Lstir/(Ag*s) + 2*tf/b_w*(ffe/fs) = 0.00$

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

$Lstir = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction

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

NUD = 9662.362

Ag = 237500.00

$f_{cE} = 20.00$

$f_{yE} = f_{yIE} = 0.00$

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

b = 250.00

d = 557.00

$f_{cE} = 20.00$

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

At local axis: 2

Integration Section: (a)

Calculation No. 3

column C1, Floor 1

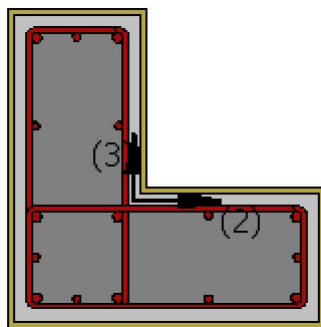
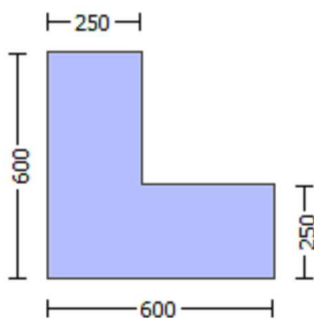
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$

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

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of γ for displacement ductility demand,
 the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
 Deformation-Controlled Action (Table C7-1, ASCE41-17).
 Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material: Steel Strength, $f_s = f_{sm} = 444.44$
 #####
 Max Height, $H_{max} = 600.00$
 Min Height, $H_{min} = 250.00$
 Max Width, $W_{max} = 600.00$
 Min Width, $W_{min} = 250.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $\epsilon_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -320830.403$
 Shear Force, $V_a = 148.2786$
 EDGE -B-
 Bending Moment, $M_b = -122390.945$
 Shear Force, $V_b = -148.2786$
 BOTH EDGES
 Axial Force, $F = -9662.362$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl,t} = 0.00$
 -Compression: $A_{sl,c} = 4121.77$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten} = 1746.726$
 -Compression: $A_{sl,com} = 829.3805$
 -Middle: $A_{sl,mid} = 1545.664$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 292301.036$
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoIo} = 379611.735$
 $V_{CoI} = 379611.735$
 $knl = 1.00$
 $displacement_ductility_demand = 0.00940177$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ ϕV_f '

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

= 1 (normal-weight concrete)

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

$M/Vd = 4.00$

$\mu_u = 320830.403$

$V_u = 148.2786$

$d = 0.8 \cdot h = 480.00$

$N_u = 9662.362$

$A_g = 150000.00$

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

where:

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

$d = 480.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$

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

$s/d = 0.3125$

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

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$

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

$s/d = 0.75$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 318865.838$

$b_w = 250.00$

displacement_ductility_demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 4.7459577E-005$

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

$M_y = 2.9341E+008$

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

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

factor = 0.30

$A_g = 237500.00$

$f'_c = 20.00$

$N = 9662.362$

$E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of δ and M_y according to Annex 7 -

```

y = Min( y_ten, y_com)
y_ten = 4.0518245E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^ 2/3) = 277.9106
d = 557.00
y = 0.3842998
A = 0.02984946
B = 0.0192317
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9662.362
b = 250.00
" = 0.07719928
y_comp = 8.1947240E-006
with fc* (12.3, (ACI 440)) = 20.42407
fc = 20.00
fl = 0.62098351
b = bmax = 600.00
h = hmax = 600.00
Ag = 237500.00
g = pt + pc + pv = 0.02959978
rc = 40.00
Ae/Ac = 0.21783041
Effective FRP thickness, tf = NL*t*cos(b1) = 1.016
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 21019.039
y = 0.38318842
A = 0.02940142
B = 0.01898202
with Es = 200000.00

```

Calculation of ratio lb/d

```

Lap Length: ld/d,min = 0.3538123
lb = 300.00
ld = 847.9072
Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 444.44
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00

```

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

At local axis: 3

Integration Section: (a)

Calculation No. 4

column C1, Floor 1

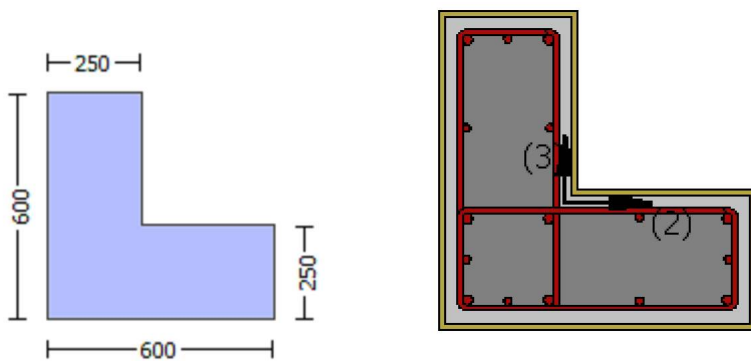
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

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: rccls

Constant Properties

Knowledge Factor, $\phi = 0.77$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00016213$

EDGE -B-

Shear Force, $V_b = -0.00016213$

BOTH EDGES

Axial Force, $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

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

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

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

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

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

with

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

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

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

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

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

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

Calculation of μ_{u1+}

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

$\phi_u = 1.1848408E-005$

$M_u = 3.9843E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \max(\phi_{cu}, \phi_{cc}) = 0.0144353$

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

From (5.4b), TBDY: $c_u = 0.0144353$
 $w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$
 where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

From EC8 A4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$$b_w = 250.00$$

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

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

From EC8 A4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$$fy_1 = 299.3701$$

$$su_1 = 0.00446911$$

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


```

Shear_factor = 1.00
lo/lou,min = lb/ld = 0.28304984
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fs1 = fs = 299.3701
with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.28304984
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fs2 = fs = 299.3701
with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 299.3701
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.32281672
Mu = MRc (4.15) = 3.9843E+008
u = su (4.1) = 1.1848408E-005

```

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

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

$= 1$

$d_b = 18.00$

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

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

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

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

$s = 150.00$

$n = 16.00$

Calculation of μ_1 -

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

$\mu = 9.6917274E-006$

$\mu_u = 2.1970E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$f_c = 20.00$

α_1 (5A.5, TBDY) = 0.002

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

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

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

we ((5.4c), TBDY) = $\alpha_1 * \mu_u^* * f_{ywe}/f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.07473805$

where $\mu_f = \alpha_1 * \mu_u^* * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\mu_{fx} = 0.06888919$

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

$\alpha_f = 0.24098246$

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

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

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

From EC8 A4.4.3(6), $\mu_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

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

$\mu_{fy} = 0.06888919$

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

$\alpha_f = 0.24098246$

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

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

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

From EC8 A4.4.3(6), $\mu_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$$E_f = 64828.00$$

$$u, f = 0.015$$

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

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$$fy_1 = 299.3701$$

$$su_1 = 0.00446911$$

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

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

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

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

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

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

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

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

$$y_2 = 0.00124738$$

$$sh_2 = 0.00431097$$

$$ft_2 = 359.2441$$

$$fy_2 = 299.3701$$

$$su_2 = 0.00446911$$

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

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

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

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

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

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

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

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

$$y_v = 0.00124738$$

$$sh_v = 0.00431097$$

```

ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
    2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
    v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
and confined core properties:
b = 540.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
    c = confinement factor = 1.0981
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
    v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.17212448
Mu = MRc (4.14) = 2.1970E+008
u = su (4.1) = 9.6917274E-006
-----

Calculation of ratio lb/ld
-----

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00
-----

Calculation of Mu2+
-----

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.1848408E-005
Mu = 3.9843E+008

```

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

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

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

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

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

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

$$f_x = 0.06888919$$

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

$$\alpha_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$f_y = 0.06888919$$

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

$$\alpha_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$s = 150.00$$

```

fywe = 555.55
fce = 20.00
From ((5A.5), TBDY), TBDY: cc = 0.00298102
c = confinement factor = 1.0981
y1 = 0.00124738
sh1 = 0.00431097
ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.28304984
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fs1 = fs = 299.3701
with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.28304984
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fs2 = fs = 299.3701
with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 299.3701
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfinedsd full section - Steel rupture

```

satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
 --->
 μ_u (4.8) = 0.32281672
 $M_u = M_{Rc}$ (4.15) = 3.9843E+008
 $u = \mu_u$ (4.1) = 1.1848408E-005

Calculation of ratio I_b/I_d

Lap Length: $I_b/I_d = 0.28304984$
 $I_b = 300.00$
 $I_d = 1059.884$
 Calculation of $I_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $d_b = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $c_b = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of μ_u

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $u = 9.6917274E-006$
 $\mu_u = 2.1970E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$
 $f_c = 20.00$
 ϕ (5A.5, TBDY) = 0.002
 Final value of ϕ : $\phi^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0144353$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\phi_u = 0.0144353$
 ϕ_c ((5.4c), TBDY) = $\phi_{se} * \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07473805$
 where $\phi_f = \phi_{af} * \phi_{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
 $\phi_{fx} = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $\phi_{af} = 1 - (\text{Unconfined area})/(\text{total area})$
 $\phi_{af} = 0.24098246$
 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), $\phi_{pf} = 2t_f/b_w = 0.008128$
 $b_w = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$f_y = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $\phi_{af} = 1 - (\text{Unconfined area})/(\text{total area})$

af = 0.24098246
 with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$
 bmax = 600.00
 hmax = 600.00
 From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128
 bw = 250.00
 effective stress from (A.35), ff,e = 703.4155

R = 40.00
 Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016
 fu,f = 1055.00
 Ef = 64828.00
 u,f = 0.015

ase = Max((((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.21805635

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

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

psh,min = Min(psh,x , psh,y) = 0.00321875

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

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875
 Lstir (Length of stirrups along Y) = 1460.00
 Astir (stirrups area) = 78.53982
 Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875
 Lstir (Length of stirrups along X) = 1460.00
 Astir (stirrups area) = 78.53982
 Asec (section area) = 237500.00

s = 150.00
 fywe = 555.55
 fce = 20.00

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

y1 = 0.00124738
 sh1 = 0.00431097

ft1 = 359.2441
 fy1 = 299.3701

su1 = 0.00446911

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

lo/lou,min = lb/ld = 0.28304984

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

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

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

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

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738
 sh2 = 0.00431097

ft2 = 359.2441
 fy2 = 299.3701

su2 = 0.00446911

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

Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 299.3701$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00124738$
 $sh_v = 0.00431097$
 $ft_v = 359.2441$
 $fy_v = 299.3701$
 $suv = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.28304984$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fs_v/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fs_v/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_v = fs = 299.3701$
 with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(fs_1/f_c) = 0.03714718$
 $2 = A_{sl,com}/(b*d)*(fs_2/f_c) = 0.0782342$
 $v = A_{sl,mid}/(b*d)*(fs_v/f_c) = 0.06922883$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(fs_1/f_c) = 0.04362424$
 $2 = A_{sl,com}/(b*d)*(fs_2/f_c) = 0.09187529$
 $v = A_{sl,mid}/(b*d)*(fs_v/f_c) = 0.08129972$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17212448$
 $\mu_u = MR_c (4.14) = 2.1970E+008$
 $u = su (4.1) = 9.6917274E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$

$$n = 16.00$$

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

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

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

$$V_{Col0} = 424229.688$$

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

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

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

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

$$M/Vd = 4.00$$

$$\mu_u = 47.24078$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

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

where:

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

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

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

$$s/d = 0.3125$$

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

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

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

$$s/d = 0.75$$

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

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

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

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.

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

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

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

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

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

$$E_f = 64828.00$$

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

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

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

$$b_w = 250.00$$

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

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

$$V_{Col0} = 424229.688$$

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

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

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

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 47.24081$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$
 where:
 $V_{s1} = 223399.91$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s1} is multiplied by $\text{Col1} = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 93083.296$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s2} is multiplied by $\text{Col2} = 1.00$
 $s/d = 0.75$
 $V_f((11-3)-(11.4), \text{ACI } 440) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe}((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

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

Constant Properties

 Knowledge Factor, $\phi = 0.77$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$
 #####

Max Height, $H_{max} = 600.00$
 Min Height, $H_{min} = 250.00$
 Max Width, $W_{max} = 600.00$
 Min Width, $W_{min} = 250.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.0981
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $\epsilon_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
 EDGE -A-
 Shear Force, $V_a = 0.00016213$
 EDGE -B-
 Shear Force, $V_b = -0.00016213$
 BOTH EDGES
 Axial Force, $F = -8883.864$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 4121.77$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{t,ten} = 1746.726$
 -Compression: $As_{l,com} = 829.3805$
 -Middle: $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.62612363$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$
 with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 3.9843E+008$
 $\mu_{u1+} = 3.9843E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 2.1970E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 3.9843E+008$
 $\mu_{u2+} = 3.9843E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $\mu_{u2-} = 2.1970E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

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

u = 1.1848408E-005
Mu = 3.9843E+008

with full section properties:

b = 250.00

d = 557.00

d' = 43.00

v = 0.0031899

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

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

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

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

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

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

fx = 0.06888919

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

af = 0.24098246

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

bmax = 600.00

hmax = 600.00

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

bw = 250.00

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

fy = 0.06888919

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

af = 0.24098246

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

bmax = 600.00

hmax = 600.00

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

bw = 250.00

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

R = 40.00

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

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

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

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

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

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

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

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

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

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

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

```

s = 150.00
fywe = 555.55
fce = 20.00
From ((5A.5), TBDY), TBDY: cc = 0.00298102
c = confinement factor = 1.0981
y1 = 0.00124738
sh1 = 0.00431097
ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 0.28304984
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.
with fs1 = fs = 299.3701
with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.28304984
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.
with fs2 = fs = 299.3701
with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/d = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 299.3701
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468

```

$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.23106236$
Case/Assumption: Unconfined full section - Steel rupture
satisfies Eq. (4.3)

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

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

--->
 $\mu_u (4.8) = 0.32281672$
 $\mu_u = M_{Rc} (4.15) = 3.9843E+008$
 $u = \mu_u (4.1) = 1.1848408E-005$

Calculation of ratio l_b / l_d

Lap Length: $l_b / l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

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

= 1

$d_b = 18.00$

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

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

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

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

$s = 150.00$

$n = 16.00$

Calculation of μ_{u1} -

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

$u = 9.6917274E-006$

$\mu_u = 2.1970E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$f_c = 20.00$

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

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} \cdot \max(\phi_{cu}, \phi_c) = 0.0144353$

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

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

where ((5.4c), TBDY) $\phi_{cu} = a_{se} \cdot \phi_{s, min} \cdot f_{ywe} / f_{ce} + \min(\phi_{fx}, \phi_{fy}) = 0.07473805$

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

$\phi_{fx} = 0.06888919$

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

$a_f = 0.24098246$

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

$b_{max} = 600.00$

$h_{max} = 600.00$

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

$b_w = 250.00$

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

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

$R = 40.00$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_f = 0.015$
 $a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$
 The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 $A_{\text{conf,max}} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{\text{conf,min}} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.
 $A_{\text{noConf}} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$
 Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

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

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

$s = 150.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
 From ((5.A5), TBDY), TBDY: $c_c = 0.00298102$
 c = confinement factor = 1.0981
 $y_1 = 0.00124738$
 $sh_1 = 0.00431097$
 $ft_1 = 359.2441$
 $fy_1 = 299.3701$
 $su_1 = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.28304984$
 $su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$
 From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,
 For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 299.3701$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.00124738$
 $sh_2 = 0.00431097$
 $ft_2 = 359.2441$
 $fy_2 = 299.3701$
 $su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_2 = fs = 299.3701$
with $Es_2 = Es = 200000.00$
 $y_v = 0.00124738$
 $sh_v = 0.00431097$
 $ft_v = 359.2441$
 $fy_v = 299.3701$
 $suv = 0.00446911$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.28304984$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fsv = fs = 299.3701$
with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.03714718$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.0782342$
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.06922883$
and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.04362424$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.09187529$
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.08129972$
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
--->
 $su (4.9) = 0.17212448$
 $Mu = MRc (4.14) = 2.1970E+008$
 $u = su (4.1) = 9.6917274E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = Min(A_{tr,x}, A_{tr,y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of μ_{2+}

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

$$\mu = 1.1848408E-005$$

$$\mu_u = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu_u: \mu_u = \text{shear_factor} * \text{Max}(\mu_o, \mu_o) = 0.0144353$$

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

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

$$\mu_u \text{ ((5.4c), TBDY)} = a_{se} * \mu_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.07473805$$

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

$$\mu_{fx} = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$\mu_{fy} = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

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

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

$$\mu_{\text{psh,min}} = \text{Min}(\mu_{\text{psh,x}}, \mu_{\text{psh,y}}) = 0.00321875$$

Expression ((5.4d), TBDY) for $\mu_{\text{psh,min}}$ has been multiplied by 0.3 according to 15.7.1.3 for members without

earthquake detailing (90° closed stirrups)

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00321875$$

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

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

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

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

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

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

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

$$s = 150.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

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

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

$$y1 = 0.00124738$$

$$sh1 = 0.00431097$$

$$ft1 = 359.2441$$

$$fy1 = 299.3701$$

$$su1 = 0.00446911$$

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

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

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

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

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

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

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

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

$$y2 = 0.00124738$$

$$sh2 = 0.00431097$$

$$ft2 = 359.2441$$

$$fy2 = 299.3701$$

$$su2 = 0.00446911$$

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

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

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

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

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

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

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

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

$$yv = 0.00124738$$

$$shv = 0.00431097$$

$$ftv = 359.2441$$

$$fyv = 299.3701$$

$$suv = 0.00446911$$

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

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

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

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

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

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

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

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

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

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

$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08915322$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.16614919$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
 --->
 $su (4.8) = 0.32281672$
 $Mu = MR_c (4.15) = 3.9843E+008$
 $u = su (4.1) = 1.1848408E-005$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Mu_2

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 9.6917274E-006$
 $Mu = 2.1970E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$
 $f_c = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0144353$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.0144353$
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$
 where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$f_y = 0.06888919$$

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

$$a_f = 0.24098246$$

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

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

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

$$b_w = 250.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

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

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

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

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

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

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$$fy_1 = 299.3701$$

$$su_1 = 0.00446911$$

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

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

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

From table 5A.1, TBDY: $es1_{nominal} = 0.08$,
For calculation of $es1_{nominal}$ 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 $fs1 = fs = 299.3701$
with $Es1 = Es = 200000.00$
 $y2 = 0.00124738$
 $sh2 = 0.00431097$
 $ft2 = 359.2441$
 $fy2 = 299.3701$
 $su2 = 0.00446911$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $lo/lou, min = lb/lb, min = 0.28304984$
 $su2 = 0.4 \cdot esu2_{nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $es2_{nominal} = 0.08$,
For calculation of $es2_{nominal}$ 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 $fs2 = fs = 299.3701$
with $Es2 = Es = 200000.00$
 $yv = 0.00124738$
 $shv = 0.00431097$
 $ftv = 359.2441$
 $fyv = 299.3701$
 $suv = 0.00446911$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $lo/lou, min = lb/ld = 0.28304984$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and yv, shv, ftv, fyv , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
with $fsv = fs = 299.3701$
with $Esv = Es = 200000.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.03714718$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.0782342$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.06922883$
and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.04362424$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.09187529$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.08129972$
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied
--->
 $su (4.9) = 0.17212448$
 $Mu = MRc (4.14) = 2.1970E+008$
 $u = su (4.1) = 9.6917274E-006$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.28304984$
 $lb = 300.00$
 $ld = 1059.884$

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

$$= 1$$

$$d_b = 18.00$$

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

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

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

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

$$s = 150.00$$

$$n = 16.00$$

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

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

$$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_n I V_{Col0}$$

$$V_{Col0} = 424229.688$$

$$k_n I = 1 \text{ (zero step-static loading)}$$

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

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

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

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

$$M/Vd = 4.00$$

$$\mu_u = 47.23669$$

$$V_u = 0.00016213$$

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

$$N_u = 8883.864$$

$$A_g = 150000.00$$

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

where:

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

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

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

$$s/d = 0.75$$

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

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

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

$$s/d = 0.3125$$

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

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

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

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

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

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

$$\text{orientation 1: } \theta = \theta_1 + 90^\circ = 90.00$$

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

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

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

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

$$E_f = 64828.00$$

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

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

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

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 424229.688$
 $knl = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 47.23667$
 $V_u = 0.00016213$
 $d = 0.8 * h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$
where:
 $V_{s1} = 93083.296$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.75$
 $V_{s2} = 223399.91$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where a is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $a_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $bw = 250.00$

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

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
At local axis: 3
Integration Section: (a)
Section Type: rdcs

Constant Properties

Knowledge Factor, $\phi = 0.77$
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 600.00$
Min Height, $H_{min} = 250.00$
Max Width, $W_{max} = 600.00$
Min Width, $W_{min} = 250.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $\epsilon_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -1.2946E+007$
Shear Force, $V_2 = -4259.045$
Shear Force, $V_3 = 148.2786$
Axial Force, $F = -9662.362$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 4121.77$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1746.726$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 1545.664$
Mean Diameter of Tension Reinforcement, $Db_L = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = \phi \cdot u = 0.0054603$
 $u = y + p = 0.0070913$

- Calculation of y -

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

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.0518245\text{E-}006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25*f_y*(l_b/l_d)^{2/3}) = 277.9106$
 $d = 557.00$
 $y = 0.3842998$
 $A = 0.02984946$
 $B = 0.0192317$
with $p_t = 0.01254381$
 $p_c = 0.00595605$
 $p_v = 0.01109992$
 $N = 9662.362$
 $b = 250.00$
 $\rho = 0.07719928$
 $y_{\text{comp}} = 8.1947240\text{E-}006$
with $f_c^* (12.3, (ACI 440)) = 20.42407$
 $f_c = 20.00$
 $f_l = 0.62098351$
 $b = b_{\text{max}} = 600.00$
 $h = h_{\text{max}} = 600.00$
 $A_g = 237500.00$
 $g = p_t + p_c + p_v = 0.02959978$
 $rc = 40.00$
 $A_e/A_c = 0.21783041$
Effective FRP thickness, $t_f = NL*t*\text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38318842$
 $A = 0.02940142$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio l_b/l_d

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

$l_b = 300.00$

$l_d = 847.9072$

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

$= 1$

$d_b = 18.00$

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

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

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

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

$s = 150.00$

$n = 16.00$

- Calculation of ρ_p -

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

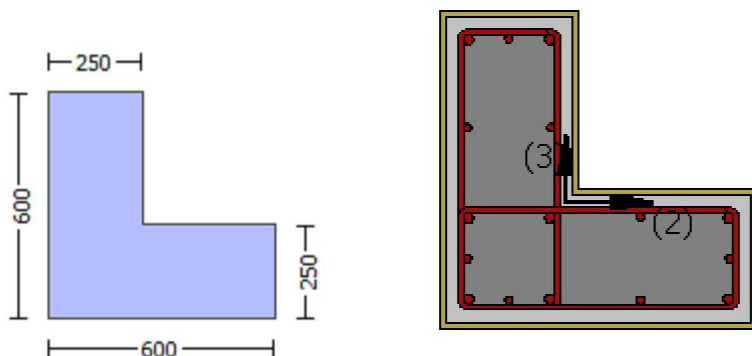
with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
 shear control ratio $V_{yE}/V_{ColOE} = 0.62612363$
 $d = 557.00$
 $s = 0.00$
 $t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$
 $A_v = 78.53982$, is the area of every stirrup
 $L_{stir} = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction
 The term $2*t_f/b_w*(f_{fe}/f_s)$ is implemented to account for FRP contribution
 where $f = 2*t_f/b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe}/f_s normalises f to steel strength
 All these variables have already been given in Shear control ratio calculation.
 $NUD = 9662.362$
 $A_g = 237500.00$
 $f_{cE} = 20.00$
 $f_{yE} = f_{yIE} = 0.00$
 $\rho_l = Area_{Tot_Long_Rein}/(b*d) = 0.02959978$
 $b = 250.00$
 $d = 557.00$
 $f_{cE} = 20.00$

 End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
 At local axis: 3
 Integration Section: (a)

Calculation No. 5

column C1, Floor 1
 Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)
 Analysis: Uniform +X
 Check: Shear capacity V_{Rd}
 Edge: End
 Local Axis: (2)



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

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$

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

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

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand,

the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as

Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $ef_u = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

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

Shear Force, $V_a = -4259.045$

EDGE -B-

Bending Moment, $M_b = 164093.879$

Shear Force, $V_b = 4259.045$

BOTH EDGES

Axial Force, $F = -9662.362$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_{lt} = 0.00$

-Compression: $As_{lc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 339075.376$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoIO} = 440357.631$

$V_{CoI} = 440357.631$

$k_n = 1.00$

$\text{displacement_ductility_demand} = 0.06818797$

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

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

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

$M/V_d = 2.00$

$\mu_u = 164093.879$

$V_u = 4259.045$

$d = 0.8 \cdot h = 480.00$

$N_u = 9662.362$

$A_g = 150000.00$

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

where:

$V_{s1} = 83775.804$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$

V_{s1} is multiplied by $\phi_{o1} = 1.00$

$s/d = 0.75$

$V_{s2} = 201061.93$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$

V_{s2} is multiplied by $\phi_{o2} = 1.00$

$s/d = 0.3125$

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

$\phi = 0.95$, for fully-wrapped sections

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

In ((11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ 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, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

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

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

$E_f = 64828.00$

$\phi_e = 0.004$, from ((11.6a), ACI 440

with $\phi_u = 0.01$

From ((11-11), ACI 440: $V_s + V_f \leq 318865.838$

$b_w = 250.00$

$\text{displacement_ductility_demand}$ is calculated as δ / y

- Calculation of δ / y for END B -

for rotation axis 3 and integ. section (b)

From analysis, chord rotation $\theta = 4.7725017E-005$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.0006999$ ((4.29), Biskinis Phd))

$M_y = 2.9341E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00

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

$\text{factor} = 0.30$

$A_g = 237500.00$

$f'_c = 20.00$

$N = 9662.362$

$$E_c I_g = 1.3974E+014$$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$$y_{\text{ten}} = 4.0518245E-006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 277.9106$$

$$d = 557.00$$

$$y = 0.3842998$$

$$A = 0.02984946$$

$$B = 0.0192317$$

$$\text{with } p_t = 0.01254381$$

$$p_c = 0.00595605$$

$$p_v = 0.01109992$$

$$N = 9662.362$$

$$b = 250.00$$

$$" = 0.07719928$$

$$y_{\text{comp}} = 8.1947240E-006$$

$$\text{with } f_c' (12.3, (\text{ACI 440})) = 20.42407$$

$$f_c = 20.00$$

$$f_l = 0.62098351$$

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

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

$$A_g = 237500.00$$

$$g = p_t + p_c + p_v = 0.02959978$$

$$r_c = 40.00$$

$$A_e / A_c = 0.21783041$$

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

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.38318842$$

$$A = 0.02940142$$

$$B = 0.01898202$$

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

Calculation of ratio l_b / l_d

$$\text{Lap Length: } l_d / l_d, \text{min} = 0.3538123$$

$$l_b = 300.00$$

$$l_d = 847.9072$$

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

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 444.44$$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

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

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 150.00$$

$$n = 16.00$$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 6

column C1, Floor 1

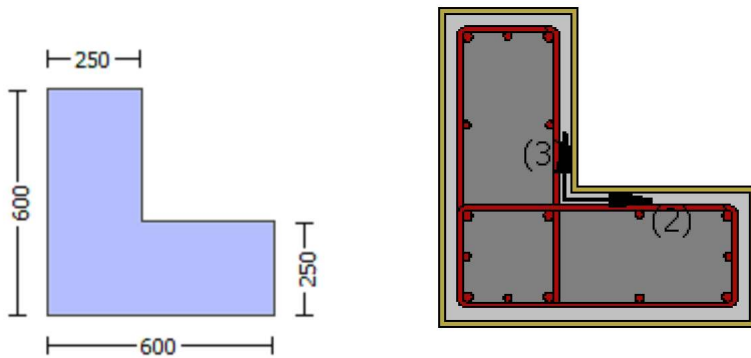
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

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: rccls

Constant Properties

Knowledge Factor, $\phi = 0.77$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $\epsilon_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i = 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, $V_a = 0.00016213$
 EDGE -B-
 Shear Force, $V_b = -0.00016213$
 BOTH EDGES
 Axial Force, $F = -8883.864$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl,t} = 0.00$
 -Compression: $A_{sl,c} = 4121.77$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten} = 1746.726$
 -Compression: $A_{sl,com} = 829.3805$
 -Middle: $A_{sl,mid} = 1545.664$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.62612363$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$
 with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 3.9843E+008$
 $\mu_{u1+} = 3.9843E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
 which is defined for the static loading combination
 $\mu_{u1-} = 2.1970E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
 direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 3.9843E+008$
 $\mu_{u2+} = 3.9843E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
 which is defined for the the static loading combination
 $\mu_{u2-} = 2.1970E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
 direction which is defined for the the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.1848408E-005$
 $M_u = 3.9843E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$

$f_c = 20.00$
 $\alpha (5A.5, TBDY) = 0.002$
 Final value of α : $\alpha = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.0144353$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\alpha = 0.0144353$
 $\alpha_e (5.4c, TBDY) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\alpha_x, \alpha_y) = 0.07473805$
 where $\alpha = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\alpha_x = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $\alpha = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\alpha = 0.24098246$
 with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$
 $b_{\max} = 600.00$
 $h_{\max} = 600.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.008128$
 $b_w = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$\alpha_y = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $\alpha = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\alpha = 0.24098246$
 with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$
 $b_{\max} = 600.00$
 $h_{\max} = 600.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.008128$
 $b_w = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$
 Effective FRP thickness, $t_f = N_L * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_f = 0.015$
 $\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$
 The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 $A_{\text{conf,max}} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{\text{conf,min}} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.
 $A_{\text{noConf}} = 105733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).
 $\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00321875$
 Expression ((5.4d), TBDY) for $\rho_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\rho_{sh,x} (5.4d, TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$\rho_{sh,y} (5.4d, TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$s = 150.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
 From ((5A.5), TBDY), TBDY: $\alpha_c = 0.00298102$
 α_c = confinement factor = 1.0981
 $y_1 = 0.00124738$
 $sh_1 = 0.00431097$
 $ft_1 = 359.2441$

```

fy1 = 299.3701
su1 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 0.28304984
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fs1 = fs = 299.3701
    with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
    c = confinement factor = 1.0981
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
    2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
    v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is not satisfied
---->
v < vs,c - RHS eq.(4.5) is satisfied
---->
su (4.8) = 0.32281672

```

$$\begin{aligned} \mu &= M R_c (4.15) = 3.9843E+008 \\ u &= s_u (4.1) = 1.1848408E-005 \end{aligned}$$

Calculation of ratio l_b/l_d

$$\begin{aligned} \text{Lap Length: } l_b/l_d &= 0.28304984 \\ l_b &= 300.00 \\ l_d &= 1059.884 \end{aligned}$$

Calculation of l_b ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$\begin{aligned} &= 1 \\ d_b &= 18.00 \\ \text{Mean strength value of all re-bars: } f_y &= 555.55 \\ f'_c &= 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)} \\ t &= 1.00 \\ s &= 0.80 \\ e &= 1.00 \\ c_b &= 25.00 \\ K_{tr} &= 2.61799 \\ A_{tr} &= \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796 \\ &\text{where } A_{tr_x}, A_{tr_y} \text{ are the sum of the area of all stirrup legs along X and Y loxal axis} \\ s &= 150.00 \\ n &= 16.00 \end{aligned}$$

Calculation of μ_{u1} -

$$\begin{aligned} &\text{Calculation of ultimate curvature } u \text{ according to 4.1, Biskinis/Fardis 2013:} \\ u &= 9.6917274E-006 \\ \mu &= 2.1970E+008 \end{aligned}$$

with full section properties:

$$\begin{aligned} b &= 600.00 \\ d &= 557.00 \\ d' &= 43.00 \\ v &= 0.00132912 \\ N &= 8883.864 \\ f_c &= 20.00 \\ c_o \text{ (5A.5, TBDY)} &= 0.002 \\ \text{Final value of } c_u: c_u^* &= \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0144353 \\ &\text{The Shear_factor is considered equal to 1 (pure moment strength)} \\ \text{From (5.4b), TBDY: } c_u &= 0.0144353 \\ v_e \text{ ((5.4c), TBDY)} &= a_s e^* s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805 \\ &\text{where } f = a_f * p_f * f_{fe} / f_{ce} \text{ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)} \end{aligned}$$

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L \cdot t \cdot \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_f = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$$fy_1 = 299.3701$$

$$su_1 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.28304984$$

$$su_1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 299.3701$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00124738$$

$$sh_2 = 0.00431097$$

$$ft_2 = 359.2441$$

$$fy_2 = 299.3701$$

$$su_2 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$$

$$su_2 = 0.4 \cdot esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, 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 fs2 = fs = 299.3701
with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 299.3701
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
and confined core properties:
b = 540.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.17212448
Mu = MRc (4.14) = 2.1970E+008
u = su (4.1) = 9.6917274E-006

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00

```

Calculation of Mu2+

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.1848408E-005$$

$$M_u = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$\phi_{co} (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_{cu}: \phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.0144353$$

$$\phi_{we} ((5.4c), \text{TBDY}) = a_{se} * \phi_{sh,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07473805$$

where $\phi_f = a_f * \phi_f^* f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$\phi_{fy} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\phi_{psh,min} = \text{Min}(\phi_{psh,x}, \phi_{psh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $\phi_{psh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\phi_{psh,x} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along } Y) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$\phi_{psh,y} ((5.4d), \text{TBDY}) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along } X) = 1460.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 150.00

fywe = 555.55

fce = 20.00

From ((5.A.5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.00124738

sh1 = 0.00431097

ft1 = 359.2441

fy1 = 299.3701

su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 0.28304984

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 0.28304984

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209

2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322

v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919

and confined core properties:

b = 190.00

d = 527.00

d' = 13.00

fcc (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied

$$\mu_u(4.8) = 0.32281672$$

$$M_u = M_{Rc}(4.15) = 3.9843E+008$$

$$u = \mu_u(4.1) = 1.1848408E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$

$$l_b = 300.00$$

$$l_d = 1059.884$$

Calculation of l_b , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 157.0796$$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis

$$s = 150.00$$

$$n = 16.00$$

Calculation of μ_u

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 9.6917274E-006$$

$$M_u = 2.1970E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \max(\mu_u, \mu_c) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.0144353$$

$$\text{we ((5.4c), TBDY) } = a_{se} * \frac{sh_{min} * f_{ywe}}{f_{ce}} + \min(f_x, f_y) = 0.07473805$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.24098246$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) \cdot (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$

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.

$A_{\text{conf,min}} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00298102$

c = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 \cdot esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 299.3701$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

```

fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
    yv = 0.00124738
    shv = 0.00431097
    ftv = 359.2441
    fyv = 299.3701
    suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
    2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
    v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
and confined core properties:
b = 540.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
    c = confinement factor = 1.0981
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
    v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.17212448
Mu = MRc (4.14) = 2.1970E+008
u = su (4.1) = 9.6917274E-006

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00

```

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$$s = 150.00$$

$$n = 16.00$$

$$\text{Calculation of Shear Strength } V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$$

$$\text{Calculation of Shear Strength at edge 1, } V_{r1} = 424229.688$$

$$V_{r1} = V_{Col} ((10.3), \text{ASCE 41-17}) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 424229.688$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f'_c = 20.00, \text{ but } f'_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$\mu_u = 47.24078$$

$$V_u = 0.00016213$$

$$d = 0.8 * h = 480.00$$

$$N_u = 8883.864$$

$$A_g = 150000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 316483.206$$

where:

$V_{s1} = 223399.91$ is calculated for section web, with:

$$d = 480.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

V_{s1} is multiplied by $\text{Col1} = 1.00$

$$s/d = 0.3125$$

$V_{s2} = 93083.296$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 150.00$$

V_{s2} is multiplied by $\text{Col2} = 1.00$

$$s/d = 0.75$$

$$V_f ((11-3)-(11.4), \text{ACI 440}) = 293495.545$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $a_1 = b_1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 557.00$$

$$f_{fe} ((11-5), \text{ACI 440}) = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 356502.845$$

$$b_w = 250.00$$

$$\text{Calculation of Shear Strength at edge 2, } V_{r2} = 424229.688$$

$$V_{r2} = V_{Col} ((10.3), \text{ASCE 41-17}) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 424229.688$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
fc' = 20.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 47.24081
Vu = 0.00016213
d = 0.8*h = 480.00
Nu = 8883.864
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 316483.206
where:
Vs1 = 223399.91 is calculated for section web, with:
d = 480.00
Av = 157079.633
fy = 444.44
s = 150.00
Vs1 is multiplied by Col1 = 1.00
s/d = 0.3125
Vs2 = 93083.296 is calculated for section flange, with:
d = 200.00
Av = 157079.633
fy = 444.44
s = 150.00
Vs2 is multiplied by Col2 = 1.00
s/d = 0.75
Vf ((11-3)-(11.4), ACI 440) = 293495.545
f = 0.95, for fully-wrapped sections
wf/sf = 1 (FRP strips adjacent to one another).
In (11.3) $\sin^2 + \cos^2$ is replaced with $(\cot^2 + \cot a)\sin a$ which is more a generalised expression,
where α is the angle of the crack direction (see KANEPE).
This later relation, considered as a function Vf(α), is implemented for every different fiber orientation ai,
as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\alpha_1 = \alpha_1 + 90^\circ = 90.00$
Vf = Min(|Vf(45, 1)|, |Vf(-45, a1)|), with:
total thickness per orientation, tf1 = NL*t/NoDir = 1.016
dfv = d (figure 11.2, ACI 440) = 557.00
ffe ((11-5), ACI 440) = 259.312
Ef = 64828.00
fe = 0.004, from (11.6a), ACI 440
with fu = 0.01
From (11-11), ACI 440: Vs + Vf <= 356502.845
bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00
#####

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = 0.00016213$

EDGE -B-

Shear Force, $V_b = -0.00016213$

BOTH EDGES

Axial Force, $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1746.726$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.62612363$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with

$M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.9843E+008$

$\mu_{u1+} = 3.9843E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u1-} = 2.1970E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.9843E+008$

$\mu_{u2+} = 3.9843E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{u2-} = 2.1970E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.1848408E-005$$

$$\mu = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$\phi_0 \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_0) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.0144353$$

$$\phi_{we} \text{ ((5.4c), TBDY)} = a_s e^* \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07473805$$

where $\phi = a_f * \phi_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$\phi_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max}} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$\phi_{sh, \min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $\phi_{sh, \min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\phi_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 237500.00$$

$$psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875$$

$$Lstir \text{ (Length of stirrups along X)} = 1460.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y1 = 0.00124738$$

$$sh1 = 0.00431097$$

$$ft1 = 359.2441$$

$$fy1 = 299.3701$$

$$su1 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.28304984$$

$$su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 299.3701$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00124738$$

$$sh2 = 0.00431097$$

$$ft2 = 359.2441$$

$$fy2 = 299.3701$$

$$su2 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.28304984$$

$$su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 299.3701$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00124738$$

$$shv = 0.00431097$$

$$ftv = 359.2441$$

$$fyv = 299.3701$$

$$suv = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.28304984$$

$$suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 299.3701$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919$$

and confined core properties:

$$b = 190.00$$

$$d = 527.00$$

$$d' = 13.00$$

$$fcc \text{ (5A.2, TBDY)} = 21.96205$$

```

cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is not satisfied
---->
v < vs,c - RHS eq.(4.5) is satisfied
---->
su (4.8) = 0.32281672
Mu = MRc (4.15) = 3.9843E+008
u = su (4.1) = 1.1848408E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00

```

Calculation of Mu1-

```

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 9.6917274E-006
Mu = 2.1970E+008

```

with full section properties:

```

b = 600.00
d = 557.00
d' = 43.00
v = 0.00132912
N = 8883.864
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0144353
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0144353
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.07473805
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
fx = 0.06888919
Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)
af = 0.24098246
with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 57233.333
bmax = 600.00
hmax = 600.00

```


From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $ff,e = 703.4155$

$fy = 0.06888919$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.24098246$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff,e = 703.4155$

$R = 40.00$

Effective FRP thickness, $tf = NL*t*\cos(b1) = 1.016$

$fu,f = 1055.00$

$Ef = 64828.00$

$u,f = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.21805635$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x \text{ ((5.4d), TBDY)} = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$psh,y \text{ ((5.4d), TBDY)} = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$fywe = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y1 = 0.00124738$

$sh1 = 0.00431097$

$ft1 = 359.2441$

$fy1 = 299.3701$

$su1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.28304984$

$su1 = 0.4*esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 299.3701$

with $Es1 = Es = 200000.00$

$y2 = 0.00124738$

```

sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
and confined core properties:
b = 540.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.17212448
Mu = MRc (4.14) = 2.1970E+008
u = su (4.1) = 9.6917274E-006

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80

```

$e = 1.00$
 $cb = 25.00$
 $Ktr = 2.61799$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.1848408E-005$
 $Mu = 3.9843E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$
 $fc = 20.00$
 $co(5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0144353$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.0144353$
 $we(5.4c, TBDY) = ase * sh, \min * fywe / fce + \text{Min}(fx, fy) = 0.07473805$
 where $f = af * pf * ffe / fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$fx = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$
 $af = 0.24098246$
 with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$
 $b_{max} = 600.00$
 $h_{max} = 600.00$
 From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.008128$
 $bw = 250.00$
 effective stress from (A.35), $ffe = 703.4155$

$fy = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$
 $af = 0.24098246$
 with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$
 $b_{max} = 600.00$
 $h_{max} = 600.00$
 From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.008128$
 $bw = 250.00$
 effective stress from (A.35), $ffe = 703.4155$

$R = 40.00$
 Effective FRP thickness, $tf = NL * t * \cos(b1) = 1.016$
 $fu, f = 1055.00$
 $Ef = 64828.00$
 $u, f = 0.015$
 $ase = \text{Max}(((A_{conf, max} - A_{noConf}) / A_{conf, max}) * (A_{conf, min} / A_{conf, max}), 0) = 0.21805635$
 The definitions of A_{noConf} , $A_{conf, min}$ and $A_{conf, max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 $A_{conf, max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{conf, min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf, max}$ by a length

equal to half the clear spacing between hoops.

AnoConf = 105733.333 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh_{min} = \min(psh_x, psh_y) = 0.00321875$

Expression ((5.4d), TBDY) for psh_{min} has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$psh_y \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{min} = lb/ld = 0.28304984$

$su_1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 299.3701$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{min} = lb/lb_{min} = 0.28304984$

$su_2 = 0.4 \cdot esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $\min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 299.3701$

with $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$suv = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{min} = lb/ld = 0.28304984$

$suv = 0.4 \cdot esuv_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 299.3701$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b \cdot d) \cdot (fs1/fc) = 0.18776209$
 $2 = Asl,com/(b \cdot d) \cdot (fs2/fc) = 0.08915322$
 $v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.16614919$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl,ten/(b \cdot d) \cdot (fs1/fc) = 0.26111925$
 $2 = Asl,com/(b \cdot d) \cdot (fs2/fc) = 0.12398468$
 $v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.23106236$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is not satisfied
 --->
 $v < vs,c$ - RHS eq.(4.5) is satisfied
 --->
 $su (4.8) = 0.32281672$
 $Mu = MRc (4.15) = 3.9843E+008$
 $u = su (4.1) = 1.1848408E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.28304984$
 $lb = 300.00$
 $ld = 1059.884$
 Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 2.61799$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of $Mu2$ -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 9.6917274E-006$
 $Mu = 2.1970E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$
 $fc = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.0144353$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.0144353$

$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.24098246$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A4.4.3(6), $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.24098246$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A4.4.3(6), $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = N_L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00298102$

c = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.28304984$
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,
 For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 299.3701$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.00124738$
 $sh_2 = 0.00431097$
 $ft_2 = 359.2441$
 $fy_2 = 299.3701$
 $su_2 = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 299.3701$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00124738$
 $sh_v = 0.00431097$
 $ft_v = 359.2441$
 $fy_v = 299.3701$
 $suv = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.28304984$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 299.3701$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.03714718$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.0782342$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.06922883$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.04362424$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.09187529$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08129972$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17212448$
 $Mu = MRc (4.14) = 2.1970E+008$
 $u = su (4.1) = 9.6917274E-006$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

Calculation of l_b , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$V_{r1} = V_{CoI} ((10.3), \text{ASCE 41-17}) = k_{nl} * V_{CoI0}$

$V_{CoI0} = 424229.688$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 47.23669$

$\nu_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 93083.296$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s1} is multiplied by $\text{Col1} = 1.00$

$s/d = 0.75$

$V_{s2} = 223399.91$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s2} is multiplied by $\text{Col2} = 1.00$

$s/d = 0.3125$

$V_f ((11-3)-(11.4), \text{ACI 440}) = 293495.545$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $a_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

$f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$
 $V_{r2} = V_{Col} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 424229.688$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 47.23667$
 $V_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$
 where:
 $V_{s1} = 93083.296$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.75$
 $V_{s2} = 223399.91$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $a_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_oDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
 At local axis: 2

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -122390.945$

Shear Force, $V_2 = 4259.045$

Shear Force, $V_3 = -148.2786$

Axial Force, $F = -9662.362$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1746.726$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $Db_L = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = \gamma \cdot u = 0.00148279$

$u = \gamma \cdot p = 0.0019257$

- Calculation of γ -

$\gamma = (M_y \cdot L_s / 3) / E_{eff} = 0.0019257 ((4.29), \text{Biskinis Phd})$

$M_y = 2.9341E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 825.4121

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$

factor = 0.30

Ag = 237500.00
fc' = 20.00
N = 9662.362
Ec*Ig = 1.3974E+014

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

y = Min(y_{ten} , y_{com})
 $y_{ten} = 4.0518245E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25*f_y*(l_b/d)^{2/3}) = 277.9106$
d = 557.00
y = 0.3842998
A = 0.02984946
B = 0.0192317
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9662.362
b = 250.00
" = 0.07719928
 $y_{comp} = 8.1947240E-006$
with $fc^* (12.3, (ACI 440)) = 20.42407$
fc = 20.00
fl = 0.62098351
b = bmax = 600.00
h = hmax = 600.00
Ag = 237500.00
g = pt + pc + pv = 0.02959978
rc = 40.00
Ae/Ac = 0.21783041
Effective FRP thickness, $t_f = NL*t*\text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
fu = 0.01
Ef = 64828.00
Ec = 21019.039
y = 0.38318842
A = 0.02940142
B = 0.01898202
with Es = 200000.00

Calculation of ratio lb/d

Lap Length: $l_d/l_d, \text{min} = 0.3538123$
lb = 300.00
ld = 847.9072
Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: $f_y = 444.44$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00

- Calculation of p -

From table 10-8: $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_{yE}/V_{CoIE} = 0.62612363$

$d = 557.00$

$s = 0.00$

$t = A_v/(b w^* s) + 2 * t_f/b w^* (f_{fe}/f_s) = A_v * L_{stir}/(A_g * s) + 2 * t_f/b w^* (f_{fe}/f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 * t_f/b w^* (f_{fe}/f_s)$ is implemented to account for FRP contribution

where $f = 2 * t_f/b w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe}/f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$NUD = 9662.362$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} = 0.00$

$p_l = \text{Area_Tot_Long_Rein}/(b * d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 7

column C1, Floor 1

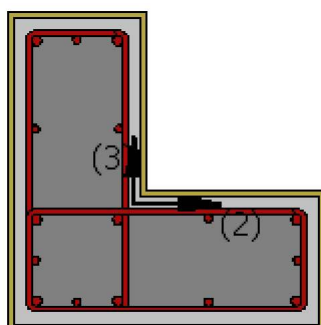
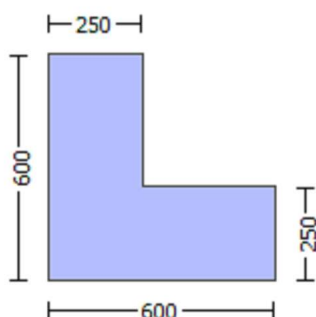
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -320830.403$

Shear Force, $V_a = 148.2786$

EDGE -B-

Bending Moment, $M_b = -122390.945$

Shear Force, $V_b = -148.2786$

BOTH EDGES

Axial Force, $F = -9662.362$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_{lt} = 0.00$

-Compression: $As_{lc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{l,ten} = 1746.726$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 339075.376$
 V_n ((10.3), ASCE 41-17) = $k_n V_{CoI0} = 440357.631$
 $V_{CoI} = 440357.631$
 $k_n = 1.00$
 $\text{displacement_ductility_demand} = 1.2067023E-005$

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f V_f$ '
 where V_f is the contribution of FRPs ((11.3), ACI 440).

$f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa ((22.5.3.1, ACI 318-14))
 $M/V_d = 2.00$
 $\mu_u = 122390.945$
 $V_u = 148.2786$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 9662.362$
 $A_g = 150000.00$
 From ((11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 284837.734$
 where:
 $V_{s1} = 201061.93$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 150.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 83775.804$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 150.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.75$
 V_f ((11-3)-(11.4), ACI 440) = 293495.545
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In ((11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where 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 θ_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from ((11.6a), ACI 440)
 with $f_u = 0.01$
 From ((11-11), ACI 440: $V_s + V_f \leq 318865.838$
 $b_w = 250.00$

$\text{displacement_ductility_demand}$ is calculated as ϕ / y

- Calculation of ϕ / y for END B -
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\phi = 2.3237426E-008$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.0019257$ ((4.29), Biskinis Phd))
 $M_y = 2.9341E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 825.4121
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$

factor = 0.30
 Ag = 237500.00
 fc' = 20.00
 N = 9662.362
 Ec*Ig = 1.3974E+014

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.0518245\text{E-}006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25*f_y*(l_b/d)^{2/3}) = 277.9106$
 $d = 557.00$
 $y = 0.3842998$
 $A = 0.02984946$
 $B = 0.0192317$
 with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9662.362$
 $b = 250.00$
 $" = 0.07719928$
 $y_{\text{comp}} = 8.1947240\text{E-}006$
 with $fc' (12.3, (ACI 440)) = 20.42407$
 $fc = 20.00$
 $fl = 0.62098351$
 $b = b_{\text{max}} = 600.00$
 $h = h_{\text{max}} = 600.00$
 $Ag = 237500.00$
 $g = pt + pc + pv = 0.02959978$
 $rc = 40.00$
 $Ae/Ac = 0.21783041$
 Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 effective strain from (12.5) and (12.12), $efe = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 21019.039$
 $y = 0.38318842$
 $A = 0.02940142$
 $B = 0.01898202$
 with $Es = 200000.00$

Calculation of ratio lb/d

Lap Length: $ld/d, \text{min} = 0.3538123$

$lb = 300.00$

$ld = 847.9072$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

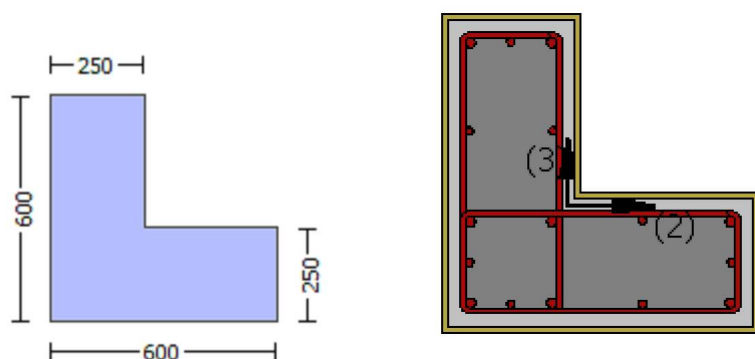
$s = 150.00$

$n = 16.00$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1
At local axis: 3
Integration Section: (b)

Calculation No. 8

column C1, Floor 1
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Chord rotation capacity (ϕ)
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: rdcs

Constant Properties

Knowledge Factor, $\phi = 0.77$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.0981
 Element Length, L = 3000.00
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length l_o = 300.00
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, t = 1.016
 Tensile Strength, f_{fu} = 1055.00
 Tensile Modulus, E_f = 64828.00
 Elongation, $ε_{fu}$ = 0.01
 Number of directions, NoDir = 1
 Fiber orientations, b_i : 0.00°
 Number of layers, NL = 1
 Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, V_a = 0.00016213
 EDGE -B-
 Shear Force, V_b = -0.00016213
 BOTH EDGES
 Axial Force, F = -8883.864
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl,t}$ = 0.00
 -Compression: $A_{sl,c}$ = 4121.77
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten}$ = 1746.726
 -Compression: $A_{sl,com}$ = 829.3805
 -Middle: $A_{sl,mid}$ = 1545.664

Calculation of Shear Capacity ratio , V_e/V_r = 0.62612363
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$
 with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 3.9843E+008$
 $\mu_{u1+} = 3.9843E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 2.1970E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 3.9843E+008$
 $\mu_{u2+} = 3.9843E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $\mu_{u2-} = 2.1970E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.1848408E-005$
 $\mu_u = 3.9843E+008$

with full section properties:
 $b = 250.00$

d = 557.00

d' = 43.00

v = 0.0031899

N = 8883.864

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0144353$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.0144353$

we ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07473805$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $fx = 0.06888919$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.24098246$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff_{e} = 703.4155$

 $fy = 0.06888919$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.24098246$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff_{e} = 703.4155$

 $R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

$fu, f = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$

$ase = \text{Max}(((A_{conf, max} - A_{noConf}) / A_{conf, max}) * (A_{conf, min} / A_{conf, max}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{conf, min}$ and $A_{conf, max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, max} = 169100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf, min} = 98400.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf, max}$ by a length

equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00321875$

Expression ((5.4d), TBDY) for psh_{min} has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 psh_x ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 psh_y ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

 $s = 150.00$

$fy_{we} = 555.55$

$f_{ce} = 20.00$

From ((5A5), TBDY), TBDY: $cc = 0.00298102$

```

c = confinement factor = 1.0981
y1 = 0.00124738
sh1 = 0.00431097
ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.28304984
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fs1 = fs = 299.3701
with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.28304984
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fs2 = fs = 299.3701
with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 299.3701
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied

```

```

--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.32281672
Mu = MRc (4.15) = 3.9843E+008
u = su (4.1) = 1.1848408E-005
-----

Calculation of ratio lb/ld
-----

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc'0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
Atr = Min(Atr,x, Atr,y) = 157.0796
where Atr,x, Atr,y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00
-----

```

Calculation of Mu1-

```

-----
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 9.6917274E-006
Mu = 2.1970E+008
-----

```

with full section properties:

```

b = 600.00
d = 557.00
d' = 43.00
v = 0.00132912
N = 8883.864
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0144353
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0144353
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.07473805
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
-----

```

fx = 0.06888919

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.24098246

with Unconfined area = ((b_{max}-2R)²+(h_{max}-2R)²)/3 = 57233.333

b_{max} = 600.00

h_{max} = 600.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128

bw = 250.00

effective stress from (A.35), ff,e = 703.4155

fy = 0.06888919

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.24098246

with Unconfined area = ((b_{max}-2R)²+(h_{max}-2R)²)/3 = 0.00

b_{max} = 600.00

hmax = 600.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u,f = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$
The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$psh,y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

s = 150.00
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
c = confinement factor = 1.0981

$y1 = 0.00124738$
 $sh1 = 0.00431097$
 $ft1 = 359.2441$
 $fy1 = 299.3701$
 $su1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/ld = 0.28304984$

$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 299.3701$

with $Es1 = Es = 200000.00$

$y2 = 0.00124738$
 $sh2 = 0.00431097$
 $ft2 = 359.2441$
 $fy2 = 299.3701$
 $su2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/lb,min = 0.28304984$

$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,
For calculation of $es_{u2_nominal}$ and y_2 , sh_2, ft_2, fy_2 , it is considered
characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.
 y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_2 = fs = 299.3701$
with $Es_2 = Es = 200000.00$
 $y_v = 0.00124738$
 $sh_v = 0.00431097$
 $ft_v = 359.2441$
 $fy_v = 299.3701$
 $s_{uv} = 0.00446911$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.28304984$
 $s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,
considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY
For calculation of $es_{uv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered
characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.
 y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_v = fs = 299.3701$
with $Es_v = Es = 200000.00$
 $1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.03714718$
 $2 = As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.0782342$
 $v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.06922883$
and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.04362424$
 $2 = As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.09187529$
 $v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.08129972$
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
--->
 $su (4.9) = 0.17212448$
 $Mu = MR_c (4.14) = 2.1970E+008$
 $u = su (4.1) = 9.6917274E-006$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.28304984$
 $lb = 300.00$
 $ld = 1059.884$
Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
 $db = 18.00$
Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.1848408E-005$$

$$\mu = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.0144353$$

$$w_e((5.4c), TBDY) = a_s e * \sigma_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_s e = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x}((5.4d), TBDY) = L_{stir} * A_{stir}/(A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along } Y) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.00124738

sh1 = 0.00431097

ft1 = 359.2441

fy1 = 299.3701

su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.28304984

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.28304984

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209

2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322

v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919

and confined core properties:

b = 190.00

d = 527.00

$d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
 --->
 $su (4.8) = 0.32281672$
 $Mu = MR_c (4.15) = 3.9843E+008$
 $u = su (4.1) = 1.1848408E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Mu_2 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 9.6917274E-006$
 $Mu = 2.1970E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$
 $f_c = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0144353$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.0144353$
 $we ((5.4c), TBDY) = ase^* sh, \min * f_{ywe}/f_{ce} + \text{Min}(fx, fy) = 0.07473805$
 where $f = af * pf * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
 $fx = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$
 $af = 0.24098246$
 with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

bmax = 600.00
hmax = 600.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

fy = 0.06888919
Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$
af = 0.24098246
with Unconfined area = $((bmax-2R)^2 + (hmax-2R)^2)/3 = 0.00$
bmax = 600.00
hmax = 600.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase = $Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.21805635$
The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
Aconf,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.
AnoConf = 105733.333 is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).
psh,min = $Min(psh,x, psh,y) = 0.00321875$
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = $Lstir*Astir/(Asec*s) = 0.00321875$
Lstir (Length of stirrups along Y) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = $Lstir*Astir/(Asec*s) = 0.00321875$
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 150.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
c = confinement factor = 1.0981
y1 = 0.00124738
sh1 = 0.00431097
ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
lo/lou,min = $lb/ld = 0.28304984$
su1 = $0.4*esu1_nominal ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu1_nominal = 0.08$,
For calculation of $esu1_nominal$ and y1, sh1, ft1, fy1, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
y1, sh1, ft1, fy1, are also multiplied by $Min(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs1 = fs = 299.3701$

```

    with Es1 = Es = 200000.00
    y2 = 0.00124738
    sh2 = 0.00431097
    ft2 = 359.2441
    fy2 = 299.3701
    su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
    yv = 0.00124738
    shv = 0.00431097
    ftv = 359.2441
    fyv = 299.3701
    suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
    2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
    v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
    and confined core properties:
    b = 540.00
    d = 527.00
    d' = 13.00
    fcc (5A.2, TBDY) = 21.96205
    cc (5A.5, TBDY) = 0.00298102
    c = confinement factor = 1.0981
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
    v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
    Case/Assumption: Unconfined full section - Steel rupture
    ' satisfies Eq. (4.3)
    --->
    v < vs,y2 - LHS eq.(4.5) is satisfied
    --->
    su (4.9) = 0.17212448
    Mu = MRc (4.14) = 2.1970E+008
    u = su (4.1) = 9.6917274E-006

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.28304984
lb = 300.00
lb = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

```

$t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$

$V_{Col0} = 424229.688$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f'_c = 20.00$, but $f'_c \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 47.24078$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 223399.91$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s1} is multiplied by $\text{Col1} = 1.00$

$s/d = 0.3125$

$V_{s2} = 93083.296$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s2} is multiplied by $\text{Col2} = 1.00$

$s/d = 0.75$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $a_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 424229.688$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 47.24081$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 223399.91$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.3125$

$V_{s2} = 93083.296$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.75$

$V_f ((11-3)-(11.4), ACI 440) = 293495.545$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $a = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcIcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

Max Height, $H_{max} = 600.00$
Min Height, $H_{min} = 250.00$
Max Width, $W_{max} = 600.00$
Min Width, $W_{min} = 250.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.0981
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $\epsilon_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 0.00016213$
EDGE -B-
Shear Force, $V_b = -0.00016213$
BOTH EDGES
Axial Force, $F = -8883.864$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 4121.77$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1746.726$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.62612363$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.9843E+008$
 $\mu_{u1+} = 3.9843E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $\mu_{u1-} = 2.1970E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.9843E+008$
 $\mu_{u2+} = 3.9843E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the static loading combination
 $\mu_{u2-} = 2.1970E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment

direction which is defined for the the static loading combination

Calculation of μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.1848408E-005$$

$$\mu_{1+} = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$\alpha_{co} \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_{1+}: \mu_{1+} = \text{shear_factor} * \text{Max}(\mu_c, \alpha_{co}) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.0144353$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = \alpha_{se} * \mu_{sh,min} * f_{ywe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.07473805$$

where $\mu_f = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{fx} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$\mu_{fy} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $\mu_{psh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_{psh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

Lstir (Length of stirrups along Y) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 150.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102
c = confinement factor = 1.0981

y1 = 0.00124738
sh1 = 0.00431097
ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209

2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322

v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
 --->
 $su (4.8) = 0.32281672$
 $Mu = MRc (4.15) = 3.9843E+008$
 $u = su (4.1) = 1.1848408E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of $Mu1$ -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 9.6917274E-006$
 $Mu = 2.1970E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$
 $f_c = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0144353$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.0144353$
 $w_e ((5.4c), TBDY) = a_s * sh_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$
 where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
 $f_x = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

af = 0.24098246
 with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$
 bmax = 600.00
 hmax = 600.00
 From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128
 bw = 250.00
 effective stress from (A.35), ff,e = 703.4155

fy = 0.06888919
 Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)
 af = 0.24098246
 with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$
 bmax = 600.00
 hmax = 600.00
 From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128
 bw = 250.00
 effective stress from (A.35), ff,e = 703.4155

R = 40.00
 Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016
 fu,f = 1055.00
 Ef = 64828.00
 u,f = 0.015
 ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.21805635
 The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 Aconf,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.
 AnoConf = 105733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).
 psh,min = Min(psh,x , psh,y) = 0.00321875
 Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875
 Lstir (Length of stirrups along Y) = 1460.00
 Astir (stirrups area) = 78.53982
 Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875
 Lstir (Length of stirrups along X) = 1460.00
 Astir (stirrups area) = 78.53982
 Asec (section area) = 237500.00

s = 150.00
 fywe = 555.55
 fce = 20.00
 From ((5.A5), TBDY), TBDY: cc = 0.00298102
 c = confinement factor = 1.0981
 y1 = 0.00124738
 sh1 = 0.00431097
 ft1 = 359.2441
 fy1 = 299.3701
 su1 = 0.00446911
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 lo/lou,min = lb/ld = 0.28304984
 su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
 From table 5A.1, TBDY: esu1_nominal = 0.08,
 For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 299.3701$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.00124738$
 $sh_2 = 0.00431097$
 $ft_2 = 359.2441$
 $fy_2 = 299.3701$
 $su_2 = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 299.3701$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00124738$
 $sh_v = 0.00431097$
 $ft_v = 359.2441$
 $fy_v = 299.3701$
 $suv = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.28304984$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 299.3701$
 with $Esv = Es = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.03714718$
 $2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.0782342$
 $v = A_{sl,mid}/(b \cdot d) \cdot (fsv/f_c) = 0.06922883$

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, \text{TBDY}) = 21.96205$
 $cc (5A.5, \text{TBDY}) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.04362424$
 $2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.09187529$
 $v = A_{sl,mid}/(b \cdot d) \cdot (fsv/f_c) = 0.08129972$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.17212448$

$Mu = MRc (4.14) = 2.1970E+008$

$u = su (4.1) = 9.6917274E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 150.00$

$n = 16.00$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.1848408E-005$

$\mu_u = 3.9843E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

α_0 (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.0144353$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_u = 0.0144353$

we ((5.4c), TBDY) = $\alpha_{se} * \alpha_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where $f = \alpha_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.24098246$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A4.4.3(6), $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.24098246$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A4.4.3(6), $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{u,f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 105733.333 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00321875

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.00124738

sh1 = 0.00431097

ft1 = 359.2441

fy1 = 299.3701

su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/ld = 0.28304984

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/ld = 0.28304984

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $\varepsilon_{suv_nominal} = 0.08$,
 considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $\varepsilon_{suv_nominal}$ and γ_v , sh_v , ft_v , f_{yv} , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 γ_1 , sh_1 , ft_1 , f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 299.3701$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.18776209$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08915322$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.16614919$

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} \text{ (5A.2, TBDY)} = 21.96205$
 $cc \text{ (5A.5, TBDY)} = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.26111925$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12398468$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.23106236$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

---->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied

---->
 $su \text{ (4.8)} = 0.32281672$
 $Mu = MR_c \text{ (4.15)} = 3.9843E+008$
 $u = su \text{ (4.1)} = 1.1848408E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$

$l_b = 300.00$
 $l_d = 1059.884$

Calculation of l_b ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$

$db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Mu_2 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 9.6917274E-006$
 $Mu = 2.1970E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$

$N = 8883.864$
 $f_c = 20.00$
 $\alpha (5A.5, TBDY) = 0.002$
 Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.0144353$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\alpha = 0.0144353$
 $\alpha_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$
 where $f = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\alpha_f = 0.24098246$
 with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$
 $b_{max} = 600.00$
 $h_{max} = 600.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.008128$
 $b_w = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$f_y = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\alpha_f = 0.24098246$
 with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$
 $b_{max} = 600.00$
 $h_{max} = 600.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.008128$
 $b_w = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$
 Effective FRP thickness, $t_f = N L * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_f = 0.015$
 $\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$
 The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 $A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.
 $A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).
 $\rho_{sh,min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00321875$
 Expression ((5.4d), TBDY) for $\rho_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\rho_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$\rho_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$s = 150.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
 From ((5A.5), TBDY), TBDY: $\alpha_c = 0.00298102$
 α_c = confinement factor = 1.0981
 $\gamma_1 = 0.00124738$
 $\text{sh}_1 = 0.00431097$

```

ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE41-17.
    with fs1 = fs = 299.3701
    with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
and confined core properties:
b = 540.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
    c = confinement factor = 1.0981
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
    v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.17212448
Mu = MRc (4.14) = 2.1970E+008

```


$$u = s_u(4.1) = 9.6917274E-006$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

Calculation of l_b ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 150.00$

$n = 16.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$V_{r1} = V_{Col} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 424229.688$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} + f * V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 47.23669$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 93083.296$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.75$

$V_{s2} = 223399.91$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.3125$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 293495.545$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_{b1} + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$
 $V_{r2} = V_{\text{Col}}((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{\text{Col}0}$
 $V_{\text{Col}0} = 424229.688$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 47.23667$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$
 where:
 $V_{s1} = 93083.296$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s1} is multiplied by $\text{Col}1 = 1.00$
 $s/d = 0.75$
 $V_{s2} = 223399.91$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s2} is multiplied by $\text{Col}2 = 1.00$
 $s/d = 0.3125$
 $V_f((11-3)-(11.4), \text{ACI 440}) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \theta_i)$, is implemented for every different fiber orientation θ_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = \theta_{b1} + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 164093.879$

Shear Force, $V_2 = 4259.045$

Shear Force, $V_3 = -148.2786$

Axial Force, $F = -9662.362$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1746.726$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $Db_L = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \gamma \cdot u = 0.00053893$

$u = \gamma + p = 0.0006999$

- Calculation of γ -

$\gamma = (M_y \cdot L_s / 3) / E_{eff} = 0.0006999 \text{ ((4.29), Biskinis Phd)}$

$M_y = 2.9341\text{E}+008$
 $L_s = M/V$ (with $L_s > 0.1*L$ and $L_s < 2*L$) = 300.00
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 4.1921\text{E}+013$
 $\text{factor} = 0.30$
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9662.362$
 $E_c * I_g = 1.3974\text{E}+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.0518245\text{E}-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b/I_d)^{2/3}) = 277.9106$
 $d = 557.00$
 $y = 0.3842998$
 $A = 0.02984946$
 $B = 0.0192317$
 with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9662.362$
 $b = 250.00$
 $" = 0.07719928$
 $y_{comp} = 8.1947240\text{E}-006$
 with $f_c' (12.3, (ACI 440)) = 20.42407$
 $f_c = 20.00$
 $f_l = 0.62098351$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $A_g = 237500.00$
 $g = pt + pc + pv = 0.02959978$
 $rc = 40.00$
 $A_e/A_c = 0.21783041$
 Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38318842$
 $A = 0.02940142$
 $B = 0.01898202$
 with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Lap Length: $I_d/I_{d,min} = 0.3538123$
 $I_b = 300.00$
 $I_d = 847.9072$
 Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 444.44$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

s = 150.00
n = 16.00

- Calculation of p -

From table 10-8: $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$
shear control ratio $V_{yE}/V_{Col0E} = 0.62612363$

d = 557.00

s = 0.00

$t = A_v/(b_w \cdot s) + 2 \cdot t_f/b_w \cdot (f_{fe}/f_s) = A_v \cdot L_{stir}/(A_g \cdot s) + 2 \cdot t_f/b_w \cdot (f_{fe}/f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 \cdot t_f/b_w \cdot (f_{fe}/f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f/b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe}/f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$N_{UD} = 9662.362$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$p_l = \text{Area_Tot_Long_Rein}/(b \cdot d) = 0.02959978$

b = 250.00

d = 557.00

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 9

column C1, Floor 1

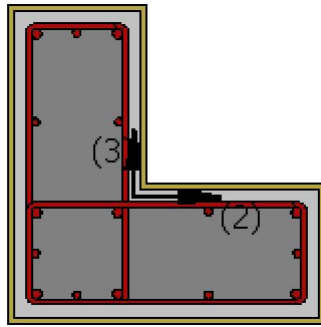
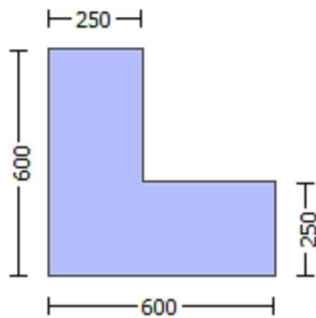
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcls

Constant Properties

Knowledge Factor, $\gamma = 0.77$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $ef_u = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -1.0749E+007$

Shear Force, $V_a = -3536.316$

EDGE -B-

Bending Moment, Mb = 136240.323

Shear Force, Vb = 3536.316

BOTH EDGES

Axial Force, F = -9530.256

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: Aslt = 0.00

-Compression: Aslc = 4121.77

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten = 1746.726

-Compression: Asl,com = 829.3805

-Middle: Asl,mid = 1545.664

Mean Diameter of Tension Reinforcement, DbL,ten = 17.71429

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = ϕV_n = 292291.023

V_n ((10.3), ASCE 41-17) = knl*VColO = 379598.731

VCol = 379598.731

knl = 1.00

displacement_ductility_demand = 0.01483887

NOTE: In expression (10-3) 'Vs' is replaced by ' $\phi V_s + \phi V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

$\mu_u = 1.0749E+007$

$V_u = 3536.316$

$d = 0.8 \cdot h = 480.00$

$N_u = 9530.256$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 284837.734$

where:

$V_{s1} = 83775.804$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$

V_{s1} is multiplied by Col1 = 1.00

$s/d = 0.75$

$V_{s2} = 201061.93$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$

V_{s2} is multiplied by Col2 = 1.00

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 293495.545

$\phi = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ 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: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$\phi_e = 0.004$, from (11.6a), ACI 440

with $\phi_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 318865.838$

$b_w = 250.00$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END A -
for rotation axis 3 and integ. section (a)

From analysis, chord rotation $\theta = 0.00010522$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00709067$ ((4.29), Biskinis Phd))
 $M_y = 2.9338E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3039.544
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$
 $factor = 0.30$
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9530.256$
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \min(y_{ten}, y_{com})$
 $y_{ten} = 4.0516275E-006$
with ((10.1), ASCE 41-17) $f_y = \min(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 277.9106$
 $d = 557.00$
 $y = 0.38426988$
 $A = 0.02984605$
 $B = 0.01922829$
with $p_t = 0.01254381$
 $p_c = 0.00595605$
 $p_v = 0.01109992$
 $N = 9530.256$
 $b = 250.00$
 $\rho = 0.07719928$
 $y_{comp} = 8.1950430E-006$
with $f_c' (12.3, (ACI 440)) = 20.42407$
 $f_c = 20.00$
 $f_l = 0.62098351$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $A_g = 237500.00$
 $g = p_t + p_c + p_v = 0.02959978$
 $r_c = 40.00$
 $A_e / A_c = 0.21783041$
Effective FRP thickness, $t_f = N L * t * \cos(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38317351$
 $A = 0.02940413$
 $B = 0.01898202$
with $E_s = 200000.00$

Calculation of ratio l_b / l_d

Lap Length: $l_d / l_{d,min} = 0.3538123$
 $l_b = 300.00$
 $l_d = 847.9072$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$

db = 18.00

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.61799

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = 150.00

n = 16.00

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 10

column C1, Floor 1

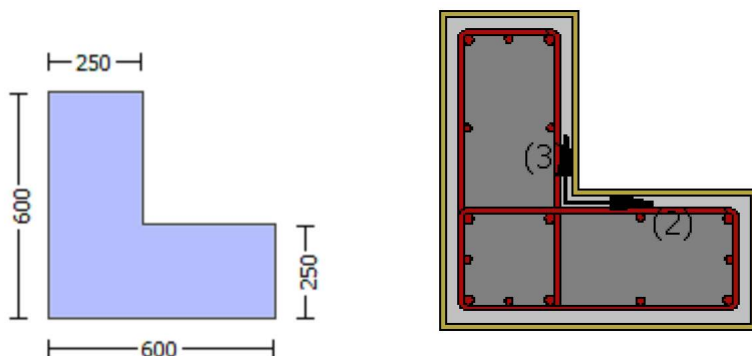
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rdcS

Constant Properties

Knowledge Factor, $\gamma = 0.77$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

Max Height, $H_{max} = 600.00$
Min Height, $H_{min} = 250.00$
Max Width, $W_{max} = 600.00$
Min Width, $W_{min} = 250.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.0981
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $\epsilon_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 0.00016213$
EDGE -B-
Shear Force, $V_b = -0.00016213$
BOTH EDGES
Axial Force, $F = -8883.864$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 4121.77$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1746.726$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.62612363$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 3.9843E+008$
 $\mu_{u1+} = 3.9843E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $\mu_{u1-} = 2.1970E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 3.9843E+008$
 $\mu_{u2+} = 3.9843E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the static loading combination
 $\mu_{u2-} = 2.1970E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment

direction which is defined for the the static loading combination

Calculation of μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.1848408E-005$$

$$\mu_{1+} = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$\alpha_{co} \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_{1+}: \mu_{1+}^* = \text{shear_factor} * \text{Max}(\mu_{1+}, \alpha_{co}) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{1+} = 0.0144353$$

$$\mu_{1+} \text{ ((5.4c), TBDY)} = \alpha_{se} * \mu_{1+,min} * f_{ywe}/f_{ce} + \text{Min}(\mu_{1+,fx}, \mu_{1+,fy}) = 0.07473805$$

where $\mu_{1+,fx} = \alpha_f * \rho_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_{1+,fx} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$\mu_{1+,fy} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(\beta_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\mu_{psh,min} = \text{Min}(\mu_{psh,x}, \mu_{psh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $\mu_{psh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_{psh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

Lstir (Length of stirrups along Y) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 150.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.00124738

sh1 = 0.00431097

ft1 = 359.2441

fy1 = 299.3701

su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.28304984

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.28304984

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209

2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322

v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26111925$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.12398468$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.23106236$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
 --->
 $su (4.8) = 0.32281672$
 $Mu = MRc (4.15) = 3.9843E+008$
 $u = su (4.1) = 1.1848408E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of $Mu1$ -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 9.6917274E-006$
 $Mu = 2.1970E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$
 $f_c = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0144353$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.0144353$
 $we ((5.4c), TBDY) = ase * sh_{\min} * f_{ywe}/f_{ce} + \text{Min}(fx, fy) = 0.07473805$
 where $f = af * pf * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
 $fx = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

af = 0.24098246
 with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$
 bmax = 600.00
 hmax = 600.00
 From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128
 bw = 250.00
 effective stress from (A.35), ff,e = 703.4155

fy = 0.06888919
 Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)
 af = 0.24098246
 with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$
 bmax = 600.00
 hmax = 600.00
 From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128
 bw = 250.00
 effective stress from (A.35), ff,e = 703.4155

R = 40.00
 Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016
 fu,f = 1055.00
 Ef = 64828.00
 u,f = 0.015
 ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.21805635
 The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 Aconf,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.
 AnoConf = 105733.333 is the unconfined core area which is equal to bi2/6 as defined at (A.2).
 psh,min = Min(psh,x , psh,y) = 0.00321875
 Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875
 Lstir (Length of stirrups along Y) = 1460.00
 Astir (stirrups area) = 78.53982
 Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875
 Lstir (Length of stirrups along X) = 1460.00
 Astir (stirrups area) = 78.53982
 Asec (section area) = 237500.00

s = 150.00
 fywe = 555.55
 fce = 20.00
 From ((5.A5), TBDY), TBDY: cc = 0.00298102
 c = confinement factor = 1.0981
 y1 = 0.00124738
 sh1 = 0.00431097
 ft1 = 359.2441
 fy1 = 299.3701
 su1 = 0.00446911
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 lo/lou,min = lb/ld = 0.28304984
 su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
 From table 5A.1, TBDY: esu1_nominal = 0.08,
 For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs1 = fs = 299.3701$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00124738$
 $sh2 = 0.00431097$
 $ft2 = 359.2441$
 $fy2 = 299.3701$
 $su2 = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/lb, min = 0.28304984$
 $su2 = 0.4 \cdot esu2_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs2 = fs = 299.3701$
 with $Es2 = Es = 200000.00$
 $yv = 0.00124738$
 $shv = 0.00431097$
 $ftv = 359.2441$
 $fyv = 299.3701$
 $suv = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/ld = 0.28304984$
 $suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 299.3701$
 with $Esv = Es = 200000.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.03714718$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.0782342$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.06922883$

and confined core properties:

$b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.04362424$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.09187529$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.08129972$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < vs, y2$ - LHS eq.(4.5) is satisfied

$su (4.9) = 0.17212448$

$Mu = MRc (4.14) = 2.1970E+008$

$u = su (4.1) = 9.6917274E-006$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.28304984$

$lb = 300.00$

$ld = 1059.884$

Calculation of lb, min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 150.00$

$n = 16.00$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.1848408E-005$

$\mu_u = 3.9843E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.0144353$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_u = 0.0144353$

we ((5.4c), TBDY) = $\alpha s e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where $f = \alpha f_p f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.24098246$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A4.4.3(6), $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.24098246$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A4.4.3(6), $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 105733.333 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00321875

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.00124738

sh1 = 0.00431097

ft1 = 359.2441

fy1 = 299.3701

su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/ld = 0.28304984

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/ld = 0.28304984

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $\epsilon_{suv_nominal} = 0.08$,
 considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $\epsilon_{suv_nominal}$ and γ_v , γ_{shv} , γ_{ftv} , γ_{fyv} , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 γ_1 , γ_{sh1} , γ_{ft1} , γ_{fy1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 299.3701$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.18776209$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08915322$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.16614919$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} \text{ (5A.2, TBDY)} = 21.96205$
 $cc \text{ (5A.5, TBDY)} = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.26111925$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12398468$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.23106236$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
 --->
 $\mu_u \text{ (4.8)} = 0.32281672$
 $\mu_u = M_{Rc} \text{ (4.15)} = 3.9843E+008$
 $u = \mu_u \text{ (4.1)} = 1.1848408E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of l_b ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $d_b = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $c_b = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of μ_u

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $u = 9.6917274E-006$
 $\mu_u = 2.1970E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$

$N = 8883.864$
 $f_c = 20.00$
 $\alpha (5A.5, TBDY) = 0.002$
 Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.0144353$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\alpha = 0.0144353$
 $\alpha_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$
 where $f = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\alpha_f = 0.24098246$
 with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$
 $b_{\max} = 600.00$
 $h_{\max} = 600.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.008128$
 $b_w = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$f_y = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\alpha_f = 0.24098246$
 with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$
 $b_{\max} = 600.00$
 $h_{\max} = 600.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.008128$
 $b_w = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$
 Effective FRP thickness, $t_f = N L * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$
 The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 $A_{\text{conf,max}} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{\text{conf,min}} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.
 $A_{\text{noConf}} = 105733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).
 $\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00321875$
 Expression ((5.4d), TBDY) for $\rho_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\rho_{sh,x} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$\rho_{sh,y} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$s = 150.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
 From ((5A5), TBDY), TBDY: $\alpha_c = 0.00298102$
 α_c = confinement factor = 1.0981
 $\gamma_1 = 0.00124738$
 $\text{sh}_1 = 0.00431097$

```

ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE41-17.
    with fs1 = fs = 299.3701
    with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
and confined core properties:
b = 540.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
    c = confinement factor = 1.0981
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
    2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
    v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.17212448
Mu = MRc (4.14) = 2.1970E+008

```

$$u = s_u(4.1) = 9.6917274E-006$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

Calculation of l_b ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 150.00$

$n = 16.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$V_{r1} = V_{Col}((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 424229.688$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} f^* V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 47.24078$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 223399.91$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.3125$

$V_{s2} = 93083.296$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.75$

$V_f((11-3)-(11.4), \text{ACI } 440) = 293495.545$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$
 $V_{r2} = V_{\text{Col}}((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{\text{Col}0}$
 $V_{\text{Col}0} = 424229.688$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 47.24081$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$
 where:
 $V_{s1} = 223399.91$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s1} is multiplied by $\text{Col}1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 93083.296$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s2} is multiplied by $\text{Col}2 = 1.00$
 $s/d = 0.75$
 $V_f((11-3)-(11.4), \text{ACI 440}) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = 0.00016213$

EDGE -B-

Shear Force, $V_b = -0.00016213$

BOTH EDGES

Axial Force, $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{l,ten} = 1746.726$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.62612363$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 3.9843\text{E}+008$

$M_{u1+} = 3.9843\text{E}+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.1970\text{E}+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 3.9843\text{E}+008$

$M_{u2+} = 3.9843\text{E}+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 2.1970\text{E}+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.1848408\text{E}-005$

$M_u = 3.9843\text{E}+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0144353$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.0144353$

ϕ_{we} ((5.4c), TBDY) = $a_{se} * \phi_{sh, \min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07473805$

where $\phi = a_f * \phi_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.24098246$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$\phi_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.24098246$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00298102$

c = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 299.3701$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 \cdot esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 299.3701$

with $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$su_v = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.28304984$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,
 considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $e_{suv_nominal}$ and y_v, sh_v, ft_v, f_{yv} , it is considered
 characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 299.3701$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.18776209$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.08915322$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.16614919$

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.26111925$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.12398468$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.23106236$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
 --->
 $s_u (4.8) = 0.32281672$
 $M_u = M_{Rc} (4.15) = 3.9843E+008$
 $u = s_u (4.1) = 1.1848408E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of l_b,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of M_u1 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 9.6917274E-006$
 $M_u = 2.1970E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } c_u = 0.0144353$$

$$w_e(5.4c, \text{TB DY}) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max}} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TB DY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x}((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} (\text{Length of stirrups along Y}) = 1460.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$p_{sh,y}((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} (\text{Length of stirrups along X}) = 1460.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TB DY), TB DY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

```

y1 = 0.00124738
sh1 = 0.00431097
ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.28304984
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fs1 = fs = 299.3701
    with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
and confined core properties:
b = 540.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->

```

su (4.9) = 0.17212448
Mu = MRc (4.14) = 2.1970E+008
u = su (4.1) = 9.6917274E-006

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.28304984

lb = 300.00

l_d = 1059.884

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

db = 18.00

Mean strength value of all re-bars: f_y = 555.55

f_c' = 20.00, but f_c'^{0.5} ≤ 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 2.61799

A_{tr} = Min(A_{tr_x}, A_{tr_y}) = 157.0796

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

s = 150.00

n = 16.00

Calculation of Mu₂₊

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.1848408E-005

Mu = 3.9843E+008

with full section properties:

b = 250.00

d = 557.00

d' = 43.00

v = 0.0031899

N = 8883.864

f_c = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.0144353

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.0144353

we ((5.4c), TBDY) = ase* sh,min*f_{ywe}/f_{ce}+Min(f_x, f_y) = 0.07473805

where f = af*pf*ffe/f_{ce} is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

f_x = 0.06888919

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.24098246

with Unconfined area = ((b_{max}-2R)²+ (h_{max}-2R)²)/3 = 57233.333

b_{max} = 600.00

h_{max} = 600.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128

bw = 250.00

effective stress from (A.35), ff,e = 703.4155

f_y = 0.06888919

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.24098246

with Unconfined area = ((b_{max}-2R)²+ (h_{max}-2R)²)/3 = 0.00

b_{max} = 600.00

h_{max} = 600.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128

bw = 250.00

effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 299.3701$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 \cdot esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs2 = fs = 299.3701$
 with $Es2 = Es = 200000.00$
 $yv = 0.00124738$
 $shv = 0.00431097$
 $ftv = 359.2441$
 $fyv = 299.3701$
 $suv = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, \min = lb/ld = 0.28304984$
 $suv = 0.4 \cdot esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv_{\text{nominal}} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{\text{nominal}}$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 299.3701$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.18776209$
 $2 = Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.08915322$
 $v = Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.16614919$

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 21.96205$
 $cc (5A.5, \text{TBDY}) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.26111925$
 $2 = Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.12398468$
 $v = Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.23106236$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < vs, y2$ - LHS eq.(4.5) is not satisfied

--->
 $v < vs, c$ - RHS eq.(4.5) is satisfied

--->
 $su (4.8) = 0.32281672$
 $Mu = MRc (4.15) = 3.9843E+008$
 $u = su (4.1) = 1.1848408E-005$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.28304984$

$lb = 300.00$
 $ld = 1059.884$

Calculation of lb, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 2.61799$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Mu2-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.6917274E-006$$

$$\mu = 2.1970E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.0144353$$

$$w_e((5.4c), \text{TBDY}) = a_s e^* s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max}} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $p_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x}((5.4d), \text{TBDY}) = L_{\text{stir}} * A_{\text{stir}}/(A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} (\text{Length of stirrups along } Y) = 1460.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$psh,y ((5.4d), TBDY) = Lstir \cdot Astir / (Asec \cdot s) = 0.00321875$$

$$Lstir \text{ (Length of stirrups along X)} = 1460.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y1 = 0.00124738$$

$$sh1 = 0.00431097$$

$$ft1 = 359.2441$$

$$fy1 = 299.3701$$

$$su1 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.28304984$$

$$su1 = 0.4 \cdot esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 299.3701$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00124738$$

$$sh2 = 0.00431097$$

$$ft2 = 359.2441$$

$$fy2 = 299.3701$$

$$su2 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.28304984$$

$$su2 = 0.4 \cdot esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 299.3701$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00124738$$

$$shv = 0.00431097$$

$$ftv = 359.2441$$

$$fyv = 299.3701$$

$$suv = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.28304984$$

$$suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 299.3701$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.03714718$$

$$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.0782342$$

$$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.06922883$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

f_{cc} (5A.2, TBDY) = 21.96205
 c_c (5A.5, TBDY) = 0.00298102
 c = confinement factor = 1.0981
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04362424$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09187529$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08129972$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 s_u (4.9) = 0.17212448
 $M_u = M_{Rc}$ (4.14) = 2.1970E+008
 $u = s_u$ (4.1) = 9.6917274E-006

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of l_b ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$
 $V_{r1} = V_{CoI}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{CoIO}$
 $V_{CoIO} = 424229.688$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 47.23669$
 $V_u = 0.00016213$
 $d = 0.8 * h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$
 where:
 $V_{s1} = 93083.296$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.75$
 $V_{s2} = 223399.91$ is calculated for section flange, with:

$d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.3125$
 $V_f((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, 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, $tf1 = NL \cdot t / \text{NoDir} = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 557.00
 $ffe((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$
 $V_{r2} = V_{Col}((10.3), ASCE 41-17) = knl \cdot V_{Col0}$
 $V_{Col0} = 424229.688$
 $knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+ f \cdot V_f}$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 47.23667$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$
 where:
 $V_{s1} = 93083.296$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.75$
 $V_{s2} = 223399.91$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.3125$
 $V_f((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$

dfv = d (figure 11.2, ACI 440) = 557.00
ffe ((11-5), ACI 440) = 259.312
Ef = 64828.00
fe = 0.004, from (11.6a), ACI 440
with fu = 0.01
From (11-11), ACI 440: Vs + Vf <= 356502.845
bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
At local axis: 2
Integration Section: (a)
Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 600.00$
Min Height, $H_{min} = 250.00$
Max Width, $W_{max} = 600.00$
Min Width, $W_{min} = 250.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $efu = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -266395.829$
Shear Force, $V2 = -3536.316$
Shear Force, $V3 = 123.1168$
Axial Force, $F = -9530.256$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 4121.77$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1746.726$
-Compression: $As_{l,com} = 829.3805$

-Middle: $Asl_{mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = u = 0.03622669$
 $u = y + p = 0.04704765$

- Calculation of y -

$y = (My * Ls / 3) / Eleff = 0.00504765$ ((4.29), Biskinis Phd))
 $My = 2.9338E+008$
 $Ls = M/V$ (with $Ls > 0.1 * L$ and $Ls < 2 * L$) = 2163.765
From table 10.5, ASCE 41_17: $Eleff = factor * Ec * Ig = 4.1921E+013$
 $factor = 0.30$
 $Ag = 237500.00$
 $fc' = 20.00$
 $N = 9530.256$
 $Ec * Ig = 1.3974E+014$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.0516275E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 277.9106$
 $d = 557.00$
 $y = 0.38426988$
 $A = 0.02984605$
 $B = 0.01922829$
with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9530.256$
 $b = 250.00$
 $" = 0.07719928$
 $y_{comp} = 8.1950430E-006$
with $fc' (12.3, (ACI 440)) = 20.42407$
 $fc = 20.00$
 $fl = 0.62098351$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $Ag = 237500.00$
 $g = pt + pc + pv = 0.02959978$
 $rc = 40.00$
 $Ae / Ac = 0.21783041$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38317351$
 $A = 0.02940413$
 $B = 0.01898202$
with $Es = 200000.00$

Calculation of ratio l_b / d

Lap Length: $ld / d_{min} = 0.3538123$
 $l_b = 300.00$

$$l_d = 847.9072$$

Calculation of λ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 444.44$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 150.00$$

$$n = 16.00$$

- Calculation of ρ -

From table 10-8: $\rho = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$

shear control ratio $V_{yE}/V_{ColOE} = 0.62612363$

$$d = 557.00$$

$$s = 0.00$$

$$t = A_v/(b_w \cdot s) + 2 \cdot t_f/b_w \cdot (f_{fe}/f_s) = A_v \cdot L_{stir}/(A_g \cdot s) + 2 \cdot t_f/b_w \cdot (f_{fe}/f_s) = 0.00$$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 \cdot t_f/b_w \cdot (f_{fe}/f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f/b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe}/f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$$N_{UD} = 9530.256$$

$$A_g = 237500.00$$

$$f'_{cE} = 20.00$$

$$f_{ytE} = f_{ylE} = 0.00$$

$$\rho_l = \text{Area_Tot_Long_Rein}/(b \cdot d) = 0.02959978$$

$$b = 250.00$$

$$d = 557.00$$

$$f'_{cE} = 20.00$$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 11

column C1, Floor 1

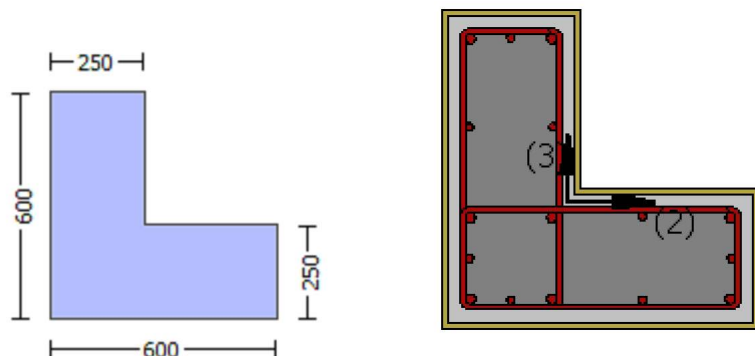
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rclcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$
Elongation, $\epsilon_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -266395.829$
Shear Force, $V_a = 123.1168$
EDGE -B-
Bending Moment, $M_b = -101614.073$
Shear Force, $V_b = -123.1168$
BOTH EDGES
Axial Force, $F = -9530.256$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 4121.77$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 1746.726$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 1545.664$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = *V_n = 292291.023$
 $V_n ((10.3), ASCE 41-17) = knl * V_{ColO} = 379598.731$
 $V_{Col} = 379598.731$
 $knl = 1.00$
 $displacement_ductility_demand = 0.00780743$

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)
 $f'_c = 16.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 266395.829$
 $V_u = 123.1168$
 $d = 0.8 * h = 480.00$
 $N_u = 9530.256$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 284837.734$
where:
 $V_{s1} = 201061.93$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 150.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 83775.804$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 150.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.75$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, 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 α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \min(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

f_{fe} ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 318865.838$

$b_w = 250.00$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END A -
for rotation axis 2 and integ. section (a)

From analysis, chord rotation $\theta = 3.9409129E-005$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00504765$ ((4.29), Biskinis Phd))

$M_y = 2.9338E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 2163.765

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9530.256$

$E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of δ and M_y according to Annex 7 -

$y = \min(y_{ten}, y_{com})$

$y_{ten} = 4.0516275E-006$

with ((10.1), ASCE 41-17) $f_y = \min(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 277.9106$

$d = 557.00$

$y = 0.38426988$

$A = 0.02984605$

$B = 0.01922829$

with $p_t = 0.01254381$

$p_c = 0.00595605$

$p_v = 0.01109992$

$N = 9530.256$

$b = 250.00$

$\alpha = 0.07719928$

$y_{comp} = 8.1950430E-006$

with $f_c' (12.3, (ACI 440)) = 20.42407$

$f_c = 20.00$

$f_l = 0.62098351$

$b = b_{max} = 600.00$

$h = h_{max} = 600.00$

$A_g = 237500.00$

$g = p_t + p_c + p_v = 0.02959978$

$r_c = 40.00$

$A_e / A_c = 0.21783041$

Effective FRP thickness, $t_f = N_L \cdot t \cdot \cos(\theta_1) = 1.016$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.38317351$

A = 0.02940413
B = 0.01898202
with Es = 200000.00

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.3538123$

$l_b = 300.00$

$l_d = 847.9072$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 150.00$

$n = 16.00$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 12

column C1, Floor 1

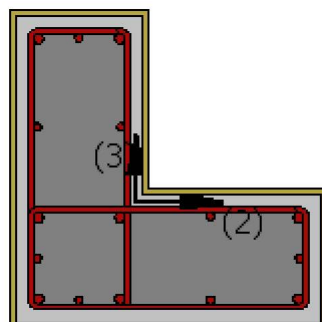
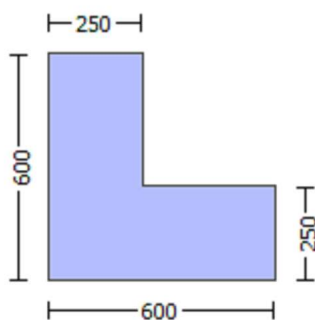
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

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: rccls

Constant Properties

Knowledge Factor, $\gamma = 0.77$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00016213$

EDGE -B-

Shear Force, $V_b = -0.00016213$

BOTH EDGES

Axial Force, $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1746.726$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 1545.664$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.62612363$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 3.9843\text{E}+008$

$\mu_{1+} = 3.9843\text{E}+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 2.1970\text{E}+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 3.9843\text{E}+008$

$\mu_{2+} = 3.9843\text{E}+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 2.1970\text{E}+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.1848408\text{E}-005$

$M_u = 3.9843\text{E}+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_s) = 0.0144353$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.0144353$

μ_s ((5.4c), TBDY) = $\alpha s_e * \text{sh_min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where $f = \alpha f_p f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as $\alpha f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha f = 0.24098246$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 57233.333$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $\alpha f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha f = 0.24098246$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 0.00$

$b_{\text{max}} = 600.00$

$h_{\text{max}} = 600.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$

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.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 299.3701$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 \cdot esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 299.3701$

with $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$su_v = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.28304984$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 299.3701$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b * d) * (fs1/fc) = 0.18776209$
 $2 = Asl_{com}/(b * d) * (fs2/fc) = 0.08915322$
 $v = Asl_{mid}/(b * d) * (fsv/fc) = 0.16614919$

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl_{ten}/(b * d) * (fs1/fc) = 0.26111925$
 $2 = Asl_{com}/(b * d) * (fs2/fc) = 0.12398468$
 $v = Asl_{mid}/(b * d) * (fsv/fc) = 0.23106236$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < vs,y2$ - LHS eq.(4.5) is not satisfied
 --->
 $v < vs,c$ - RHS eq.(4.5) is satisfied
 --->
 $su (4.8) = 0.32281672$
 $Mu = MRc (4.15) = 3.9843E+008$
 $u = su (4.1) = 1.1848408E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of l_b,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 2.61799$
 $Atr = Min(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of $Mu1$ -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 9.6917274E-006$
 $Mu = 2.1970E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } c_u = 0.0144353$$

$$w_e(5.4c, \text{TB DY}) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max}} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TB DY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x}((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} (\text{Length of stirrups along Y}) = 1460.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$p_{sh,y}((5.4d), \text{TB DY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} (\text{Length of stirrups along X}) = 1460.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TB DY), TB DY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

```

y1 = 0.00124738
sh1 = 0.00431097
ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 0.28304984
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fs1 = fs = 299.3701
    with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
and confined core properties:
b = 540.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->

```


$s_u(4.9) = 0.17212448$
 $\mu = MRC(4.14) = 2.1970E+008$
 $u = s_u(4.1) = 9.6917274E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 150.00$

$n = 16.00$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$u = 1.1848408E-005$

$\mu = 3.9843E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

$\alpha(5A.5, \text{TB DY}) = 0.002$

Final value of μ : $\mu^* = \text{shear_factor} * \max(\mu, \alpha) = 0.0144353$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY: $\mu = 0.0144353$

we ((5.4c), TB DY) = $\alpha s_e * \frac{f_{ywe}}{f_{ce}} + \min(f_x, f_y) = 0.07473805$

where $f = \alpha f_p f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06888919$

Expression ((15B.6), TB DY) is modified as $\alpha f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha f = 0.24098246$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 57233.333$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TB DY) is modified as $\alpha f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha f = 0.24098246$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 299.3701$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 \cdot esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs2 = fs = 299.3701$
 with $Es2 = Es = 200000.00$
 $yv = 0.00124738$
 $shv = 0.00431097$
 $ftv = 359.2441$
 $fyv = 299.3701$
 $suv = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, \min = lb/ld = 0.28304984$
 $suv = 0.4 \cdot esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv_{\text{nominal}} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{\text{nominal}}$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 299.3701$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.18776209$
 $2 = Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.08915322$
 $v = Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.16614919$

and confined core properties:

$b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 21.96205$
 $cc (5A.5, \text{TBDY}) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.26111925$
 $2 = Asl, \text{com} / (b \cdot d) \cdot (fs2 / fc) = 0.12398468$
 $v = Asl, \text{mid} / (b \cdot d) \cdot (fsv / fc) = 0.23106236$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < vs, y2$ - LHS eq.(4.5) is not satisfied

--->
 $v < vs, c$ - RHS eq.(4.5) is satisfied

--->
 $su (4.8) = 0.32281672$
 $Mu = MRc (4.15) = 3.9843E+008$
 $u = su (4.1) = 1.1848408E-005$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.28304984$

$lb = 300.00$
 $ld = 1059.884$

Calculation of lb, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 2.61799$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Mu2-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.6917274E-006$$

$$\mu_u = 2.1970E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, c_o) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.0144353$$

$$w_e((5.4c), TBDY) = a_s e^* s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$$

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.

$A_{\text{conf,min}} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.

$A_{\text{noConf}} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh, \min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $p_{sh, \min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x}((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$$

$$L_{\text{stir}} (\text{Length of stirrups along } Y) = 1460.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 237500.00$$

$$psh,y ((5.4d), TBDY) = Lstir \cdot Astir / (Asec \cdot s) = 0.00321875$$

$$Lstir \text{ (Length of stirrups along X)} = 1460.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y1 = 0.00124738$$

$$sh1 = 0.00431097$$

$$ft1 = 359.2441$$

$$fy1 = 299.3701$$

$$su1 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.28304984$$

$$su1 = 0.4 \cdot esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 299.3701$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00124738$$

$$sh2 = 0.00431097$$

$$ft2 = 359.2441$$

$$fy2 = 299.3701$$

$$su2 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.28304984$$

$$su2 = 0.4 \cdot esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 299.3701$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00124738$$

$$shv = 0.00431097$$

$$ftv = 359.2441$$

$$fyv = 299.3701$$

$$suv = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.28304984$$

$$suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 299.3701$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten/(b \cdot d) \cdot (fs1/fc) = 0.03714718$$

$$2 = Asl,com/(b \cdot d) \cdot (fs2/fc) = 0.0782342$$

$$v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.06922883$$

and confined core properties:

$$b = 540.00$$

$$d = 527.00$$

$$d' = 13.00$$

```

fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.17212448
Mu = MRc (4.14) = 2.1970E+008
u = su (4.1) = 9.6917274E-006

```

Calculation of ratio lb/l_d

```

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00

```

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

```

Calculation of Shear Strength at edge 1, Vr1 = 424229.688
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO
VColO = 424229.688
knl = 1 (zero step-static loading)

```

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

```

= 1 (normal-weight concrete)
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 47.24078
Vu = 0.00016213
d = 0.8*h = 480.00
Nu = 8883.864
Ag = 150000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 316483.206
where:
Vs1 = 223399.91 is calculated for section web, with:
d = 480.00
Av = 157079.633
fy = 444.44
s = 150.00
Vs1 is multiplied by Col1 = 1.00
s/d = 0.3125
Vs2 = 93083.296 is calculated for section flange, with:

```

$d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
Vs2 is multiplied by Col2 = 1.00
 $s/d = 0.75$
 $V_f((11-3)-(11.4), \text{ACI 440}) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
where a is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$
 $V_{r2} = V_{Col}((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 424229.688$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+ f} \cdot V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$\rho = 1$ (normal-weight concrete)
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 47.24081$
 $\nu_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $N_u = 8883.864$
 $A_g = 150000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$
where:
 $V_{s1} = 223399.91$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
Vs1 is multiplied by Col1 = 1.00
 $s/d = 0.3125$
 $V_{s2} = 93083.296$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
Vs2 is multiplied by Col2 = 1.00
 $s/d = 0.75$
 $V_f((11-3)-(11.4), \text{ACI 440}) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
where a is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$

<div> <div>dfv = d (figure 11.2, ACI 440) = 557.00</div> <div>ffe ((11-5), ACI 440) = 259.312</div> <div>Ef = 64828.00</div> <div>fe = 0.004, from (11.6a), ACI 440</div> <div>with fu = 0.01</div> <div>From (11-11), ACI 440: Vs + Vf <= 356502.845</div> <div>bw = 250.00</div> </div>	
<div> <div>End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1</div> <div>At local axis: 3</div> </div>	
<div> <div>Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1</div> <div>At Shear local axis: 2</div> <div>(Bending local axis: 3)</div> <div>Section Type: rdcs</div> </div>	
<div> <div>Constant Properties</div> </div>	
<div> <div>Knowledge Factor, = 0.77</div> <div>Mean strength values are used for both shear and moment calculations.</div> <div>Consequently:</div> <div>Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00</div> <div>Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44</div> <div>Concrete Elasticity, Ec = 21019.039</div> <div>Steel Elasticity, Es = 200000.00</div> <div>#####</div> <div>Note: Especially for the calculation of moment strengths,</div> <div>the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14</div> <div>Existing material: Steel Strength, fs = 1.25*fsm = 555.55</div> <div>#####</div> <div>Max Height, Hmax = 600.00</div> <div>Min Height, Hmin = 250.00</div> <div>Max Width, Wmax = 600.00</div> <div>Min Width, Wmin = 250.00</div> <div>Cover Thickness, c = 25.00</div> <div>Mean Confinement Factor overall section = 1.0981</div> <div>Element Length, L = 3000.00</div> <div>Secondary Member</div> <div>Ribbed Bars</div> <div>Ductile Steel</div> <div>Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)</div> <div>Longitudinal Bars With Ends Lapped Starting at the End Sections</div> <div>Lap Length lo = 300.00</div> <div>FRP Wrapping Data</div> <div>Type: Carbon</div> <div>Cured laminate properties (design values)</div> <div>Thickness, t = 1.016</div> <div>Tensile Strength, ffu = 1055.00</div> <div>Tensile Modulus, Ef = 64828.00</div> <div>Elongation, efu = 0.01</div> <div>Number of directions, NoDir = 1</div> <div>Fiber orientations, bi: 0.00°</div> <div>Number of layers, NL = 1</div> <div>Radius of rounding corners, R = 40.00</div> </div>	
<div> <div>Stepwise Properties</div> </div>	
<div> <div>At local axis: 2</div> <div>EDGE -A-</div> <div>Shear Force, Va = 0.00016213</div> <div>EDGE -B-</div> <div>Shear Force, Vb = -0.00016213</div> </div>	

BOTH EDGES

Axial Force, $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_{lt} = 0.00$

-Compression: $As_{lc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{l,ten} = 1746.726$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.62612363$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.9843E+008$

$Mu_{1+} = 3.9843E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.1970E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.9843E+008$

$Mu_{2+} = 3.9843E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.1970E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.1848408E-005$

$M_u = 3.9843E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

$\phi_{co} (5A.5, \text{TB DY}) = 0.002$

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.0144353$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY: $\phi_u = 0.0144353$

we ((5.4c), TB DY) = $a s_e * \phi_{u,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07473805$

where $\phi_f = a f^* p_f^* f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.06888919$

Expression ((15B.6), TB DY) is modified as $a f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a f = 0.24098246$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$\phi_{fy} = 0.06888919$

Expression ((15B.6), TB DY) is modified as $a f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a f = 0.24098246$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00

Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$psh,y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

s = 150.00

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y1 = 0.00124738$

$sh1 = 0.00431097$

$ft1 = 359.2441$

$fy1 = 299.3701$

$su1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/ld = 0.28304984$

$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 299.3701$

with $Es1 = Es = 200000.00$

$y2 = 0.00124738$

$sh2 = 0.00431097$

$ft2 = 359.2441$

$fy2 = 299.3701$

$su2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/lb,min = 0.28304984$

$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $es_{u2_nominal}$ 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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 299.3701$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00124738$
 $sh_v = 0.00431097$
 $ft_v = 359.2441$
 $fy_v = 299.3701$
 $s_{uv} = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.28304984$
 $s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), \text{TBDY}) = 0.032$
 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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = fs = 299.3701$
 with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.18776209$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08915322$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.16614919$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, \text{TBDY}) = 21.96205$
 $cc (5A.5, \text{TBDY}) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.26111925$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12398468$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.23106236$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
 --->
 $s_u (4.8) = 0.32281672$
 $\mu_u = M_{Rc} (4.15) = 3.9843E+008$
 $u = s_u (4.1) = 1.1848408E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.6917274E-006$$

$$\mu_u = 2.1970E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u = \text{shear_factor} * \text{Max}(c_u, c_o) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$w_e((5.4c), TBDY) = a_s e * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_s e = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x}((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along } Y) = 1460.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 150.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102
c = confinement factor = 1.0981

y1 = 0.00124738
sh1 = 0.00431097
ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.28304984
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701
with Es1 = Es = 200000.00

y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701
with Es2 = Es = 200000.00

yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701
with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718

2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342

v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883

and confined core properties:

b = 540.00

$d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04362424$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09187529$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08129972$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17212448$
 $Mu = MRc (4.14) = 2.1970E+008$
 $u = su (4.1) = 9.6917274E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.1848408E-005$
 $Mu = 3.9843E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$
 $f_c = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0144353$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.0144353$
 $w_e (5.4c, TBDY) = a_s^* sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$
 where $f = a_f^* p_f^* f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
 $f_x = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$
 $a_f = 0.24098246$
 with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$
 $b_{max} = 600.00$

hmax = 600.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

fy = 0.06888919
Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$
af = 0.24098246
with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$
bmax = 600.00
hmax = 600.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*\cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase = $\text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.21805635$
The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 $A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.
 $A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

psh,y ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

s = 150.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
c = confinement factor = 1.0981
y1 = 0.00124738
sh1 = 0.00431097
ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lo_{u,min} = lb/l_d = 0.28304984$
su1 = $0.4*esu1_{nominal}$ ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,
For calculation of $esu1_{nominal}$ and y1, sh1, ft1, fy1, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs1 = fs = 299.3701$
with $Es1 = Es = 200000.00$

```

y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.28304984
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fs2 = fs = 299.3701
with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 299.3701
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919

```

and confined core properties:

```

b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236

```

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

```

--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.32281672
Mu = MRc (4.15) = 3.9843E+008
u = su (4.1) = 1.1848408E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55

```


$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.6917274E-006$

$\mu_u = 2.1970E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$f_c = 20.00$

α_0 (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.0144353$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_u = 0.0144353$

μ_{ue} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$

where $f = \alpha_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06888919$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.24098246$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A4.4.3(6), $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.24098246$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

$b_{\max} = 600.00$

$h_{\max} = 600.00$

From EC8 A4.4.3(6), $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{u,f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max}} = 169100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$psh,y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 299.3701$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 299.3701$

with $Es_2 = Es = 200000.00$

$y_v = 0.00124738$

$sh_v = 0.00431097$

$ft_v = 359.2441$

$fy_v = 299.3701$

$suv = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$suv = 0.4 * esuv_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
For calculation of $e_{suv_nominal}$ and y_v , sh_v , ft_v , f_{yv} , it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 299.3701$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03714718$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0782342$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06922883$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04362424$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09187529$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08129972$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.17212448

$Mu = MR_c$ (4.14) = 2.1970E+008

$u = su$ (4.1) = 9.6917274E-006

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

Calculation of l_b ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 150.00$

$n = 16.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$V_{r1} = V_{CoI}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{CoI0}$

$V_{CoI0} = 424229.688$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} + f \cdot V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 47.23669$

$Vu = 0.00016213$

$d = 0.8 \cdot h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$
 where:
 $V_{s1} = 93083.296$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.75$
 $V_{s2} = 223399.91$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.3125$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $a_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL \cdot t / NoDir = 1.016$
 $df_v = d$ (figure 11.2, ACI 440) = 557.00
 $ffe ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$
 $V_{Col0} = 424229.688$
 $knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\beta = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 47.23667$
 $V_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$
 where:
 $V_{s1} = 93083.296$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.75$
 $V_{s2} = 223399.91$ is calculated for section flange, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$

$s = 150.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.3125$
 $V_f((11-3)-(11.4), ACI\ 440) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $a_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe}((11-5), ACI\ 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $bw = 250.00$

 End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At local axis: 2

 Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
 At local axis: 3
 Integration Section: (a)
 Section Type: rdcs

Constant Properties

 Knowledge Factor, $\phi = 0.77$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 Max Height, $H_{max} = 600.00$
 Min Height, $H_{min} = 250.00$
 Max Width, $W_{max} = 600.00$
 Min Width, $W_{min} = 250.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $efu = 0.01$
 Number of directions, $\text{NoDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -1.0749\text{E}+007$

Shear Force, $V2 = -3536.316$

Shear Force, $V3 = 123.1168$

Axial Force, $F = -9530.256$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_{lt} = 0.00$

-Compression: $As_{lc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{l,ten} = 1746.726$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $DbL = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.03779982$

$u = y + p = 0.04909067$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00709067$ ((4.29), Biskinis Phd))

$M_y = 2.9338\text{E}+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3039.544

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 4.1921\text{E}+013$

factor = 0.30

$A_g = 237500.00$

$f_c' = 20.00$

$N = 9530.256$

$E_c * I_g = 1.3974\text{E}+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 4.0516275\text{E}-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 277.9106$

$d = 557.00$

$y = 0.38426988$

$A = 0.02984605$

$B = 0.01922829$

with $p_t = 0.01254381$

$p_c = 0.00595605$

$p_v = 0.01109992$

$N = 9530.256$

$b = 250.00$

$" = 0.07719928$

$y_{comp} = 8.1950430\text{E}-006$

with f_c^* (12.3, (ACI 440)) = 20.42407

$f_c = 20.00$

$f_l = 0.62098351$

$b = b_{max} = 600.00$

$h = h_{max} = 600.00$

$A_g = 237500.00$

$g = p_t + p_c + p_v = 0.02959978$

$r_c = 40.00$

$A_e / A_c = 0.21783041$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$f_u = 0.01$

Ef = 64828.00
Ec = 21019.039
y = 0.38317351
A = 0.02940413
B = 0.01898202
with Es = 200000.00

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.3538123$

$l_b = 300.00$

$l_d = 847.9072$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

- Calculation of p -

From table 10-8: $p = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_y E / V_{col} E = 0.62612363$

$d = 557.00$

$s = 0.00$

$t = A_v / (b_w s) + 2 t_f / b_w (f_{fe} / f_s) = A_v L_{stir} / (A_g s) + 2 t_f / b_w (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 t_f / b_w (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$NUD = 9530.256$

$A_g = 237500.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b d) = 0.02959978$

$b = 250.00$

$d = 557.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 13

column C1, Floor 1

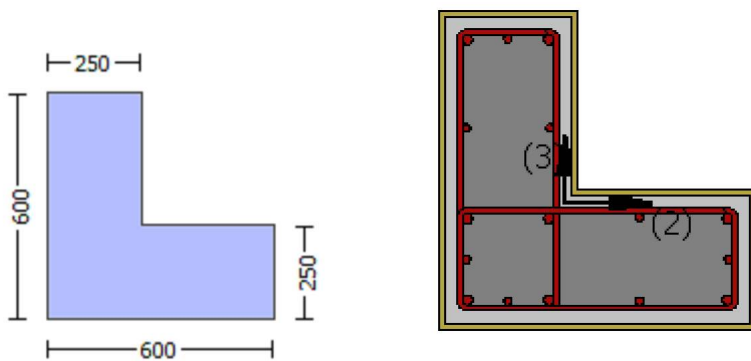
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -1.0749E+007$

Shear Force, $V_a = -3536.316$

EDGE -B-

Bending Moment, $M_b = 136240.323$

Shear Force, $V_b = 3536.316$

BOTH EDGES

Axial Force, $F = -9530.256$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1746.726$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 1545.664$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.71429$

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity $V_R = V_n = 339055.351$

V_n ((10-3), ASCE 41-17) = $k_n \cdot V_{CoI} = 440331.624$

$V_{CoI} = 440331.624$

$k_n = 1.00$

$displacement_ductility_demand = 0.05662636$

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)

$f'_c = 16.00$, but $f'_c^{0.5} \leq 8.3$ MPa ((22.5.3.1, ACI 318-14)

$M/V_d = 2.00$

$M_u = 136240.323$

$V_u = 3536.316$

$d = 0.8 \cdot h = 480.00$

$N_u = 9530.256$

$A_g = 150000.00$

From ((11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 284837.734$

where:

$V_{s1} = 83775.804$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.75$

$V_{s2} = 201061.93$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 150.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.3125$
 $V_f((11-3)-(11.4), ACI\ 440) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 $\ln(11.3) \sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe}((11-5), ACI\ 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 318865.838$
 $bw = 250.00$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END B -
 for rotation axis 3 and integ. section (b)

From analysis, chord rotation $\theta = 3.9629525E-005$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00069984$ ((4.29), Biskinis Phd))
 $M_y = 2.9338E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921E+013$
 $\text{factor} = 0.30$
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9530.256$
 $E_c \cdot I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of δ and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.0516275E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 277.9106$
 $d = 557.00$
 $y = 0.38426988$
 $A = 0.02984605$
 $B = 0.01922829$
 with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9530.256$
 $b = 250.00$
 $" = 0.07719928$
 $y_{comp} = 8.1950430E-006$
 with $f_c' (12.3, (ACI\ 440)) = 20.42407$
 $f_c = 20.00$
 $f_l = 0.62098351$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $A_g = 237500.00$
 $g = pt + pc + pv = 0.02959978$
 $rc = 40.00$

$$A_e/A_c = 0.21783041$$

$$\text{Effective FRP thickness, } t_f = N_L \cdot t \cdot \cos(b_1) = 1.016$$

$$\text{effective strain from (12.5) and (12.12), } \epsilon_{fe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.38317351$$

$$A = 0.02940413$$

$$B = 0.01898202$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio I_b/I_d

$$\text{Lap Length: } I_d/I_{d,\min} = 0.3538123$$

$$I_b = 300.00$$

$$I_d = 847.9072$$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 444.44$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 150.00$$

$$n = 16.00$$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 14

column C1, Floor 1

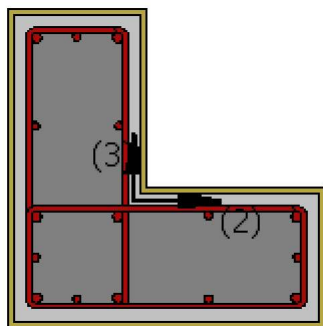
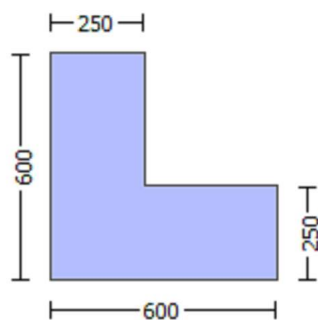
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

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: rccls

Constant Properties

Knowledge Factor, $\gamma = 0.77$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00016213$

EDGE -B-

Shear Force, $V_b = -0.00016213$

BOTH EDGES

Axial Force, $F = -8883.864$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_{lt} = 0.00$

-Compression: $As_{lc} = 4121.77$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{l,ten} = 1746.726$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.62612363$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.9843E+008$

$Mu_{1+} = 3.9843E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.1970E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.9843E+008$

$Mu_{2+} = 3.9843E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.1970E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.1848408E-005$

$M_u = 3.9843E+008$

with full section properties:

$b = 250.00$

$d = 557.00$

$d' = 43.00$

$v = 0.0031899$

$N = 8883.864$

$f_c = 20.00$

$\phi_{co} (5A.5, TBDY) = 0.002$

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.0144353$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.0144353$

we ((5.4c), TBDY) $= a_{se} * \phi_{u,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07473805$

where $\phi_f = a_f * \phi_p * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.06888919$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.24098246$

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), $\phi_p = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$\phi_{fy} = 0.06888919$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.24098246$

with Unconfined area $= ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00

Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$psh,y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

s = 150.00

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y1 = 0.00124738$

$sh1 = 0.00431097$

$ft1 = 359.2441$

$fy1 = 299.3701$

$su1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/ld = 0.28304984$

$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 299.3701$

with $Es1 = Es = 200000.00$

$y2 = 0.00124738$

$sh2 = 0.00431097$

$ft2 = 359.2441$

$fy2 = 299.3701$

$su2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/lb,min = 0.28304984$

$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $es_{u2_nominal}$ 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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 299.3701$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00124738$
 $sh_v = 0.00431097$
 $ft_v = 359.2441$
 $fy_v = 299.3701$
 $s_{uv} = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.28304984$
 $s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), \text{TBDY}) = 0.032$
 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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = fs = 299.3701$
 with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.18776209$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08915322$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.16614919$
 and confined core properties:
 $b = 190.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, \text{TBDY}) = 21.96205$
 $cc (5A.5, \text{TBDY}) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.26111925$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.12398468$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.23106236$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
 --->
 $su (4.8) = 0.32281672$
 $\mu_u = M_{Rc} (4.15) = 3.9843E+008$
 $u = su (4.1) = 1.1848408E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.6917274E-006$$

$$Mu = 2.1970E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u = \text{shear_factor} * \text{Max}(c_u, c_o) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_s e = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875
Lstir (Length of stirrups along X) = 1460.00
Astir (stirrups area) = 78.53982
Asec (section area) = 237500.00

s = 150.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102
c = confinement factor = 1.0981

y1 = 0.00124738
sh1 = 0.00431097
ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.28304984

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.28304984

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with fsv = fs = 299.3701

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718

2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342

v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883

and confined core properties:

b = 540.00

$d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.04362424$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09187529$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08129972$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17212448$
 $Mu = MRc (4.14) = 2.1970E+008$
 $u = su (4.1) = 9.6917274E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.1848408E-005$
 $Mu = 3.9843E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.0031899$
 $N = 8883.864$
 $f_c = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0144353$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.0144353$
 $w_e ((5.4c), TBDY) = a_s^* sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$
 where $f = a_f^* p_f^* f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
 $f_x = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$
 $a_f = 0.24098246$
 with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$
 $b_{max} = 600.00$

hmax = 600.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

fy = 0.06888919
Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$
af = 0.24098246
with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$
bmax = 600.00
hmax = 600.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

R = 40.00
Effective FRP thickness, $tf = NL*t*\cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
ase = $\text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.21805635$
The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 $A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.
 $A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

psh,y ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

s = 150.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: $cc = 0.00298102$
c = confinement factor = 1.0981
y1 = 0.00124738
sh1 = 0.00431097
ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.28304984$
 $su1 = 0.4*esu1_{nominal}$ ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,
For calculation of $esu1_{nominal}$ and y1, sh1, ft1, fy1, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs1 = fs = 299.3701$
with $Es1 = Es = 200000.00$

```

y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.28304984
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fs2 = fs = 299.3701
with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 299.3701
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.32281672
Mu = MRc (4.15) = 3.9843E+008
u = su (4.1) = 1.1848408E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55

```

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 9.6917274E-006$

$\mu_u = 2.1970E+008$

with full section properties:

$b = 600.00$

$d = 557.00$

$d' = 43.00$

$v = 0.00132912$

$N = 8883.864$

$f_c = 20.00$

α_1 (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.0144353$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_u = 0.0144353$

μ_{ue} ((5.4c), TBDY) = $\alpha_1 \mu_u \leq \mu_{ue} = 0.07473805$

where $\mu_{ue} = \mu_u \cdot \mu_{fe}/\mu_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\mu_{fe} = 0.06888919$

Expression ((15B.6), TBDY) is modified as $\mu_{fe} = 1 - (\text{Unconfined area})/(\text{total area})$

$\mu_{fe} = 0.24098246$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A4.4.3(6), $\mu_{fe} = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $\mu_{fe} = 703.4155$

$\mu_{fe} = 0.06888919$

Expression ((15B.6), TBDY) is modified as $\mu_{fe} = 1 - (\text{Unconfined area})/(\text{total area})$

$\mu_{fe} = 0.24098246$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A4.4.3(6), $\mu_{fe} = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $\mu_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = N L^* t \cos(\beta_1) = 1.016$

$f_u, f = 1055.00$

$E_f = 64828.00$

$\mu_{u, f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{conf, max} - A_{noConf})/A_{conf, max}) * (A_{conf, min}/A_{conf, max}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{conf, min}$ and $A_{conf, max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf, max} = 169100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$psh,y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y1 = 0.00124738$

$sh1 = 0.00431097$

$ft1 = 359.2441$

$fy1 = 299.3701$

$su1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/ld = 0.28304984$

$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 299.3701$

with $Es1 = Es = 200000.00$

$y2 = 0.00124738$

$sh2 = 0.00431097$

$ft2 = 359.2441$

$fy2 = 299.3701$

$su2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/lb,min = 0.28304984$

$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 299.3701$

with $Es2 = Es = 200000.00$

$yv = 0.00124738$

$shv = 0.00431097$

$ftv = 359.2441$

$fyv = 299.3701$

$suv = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/ld = 0.28304984$

$suv = 0.4 * esuv_nominal \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv_nominal}$ and y_v , sh_v , ft_v , f_{yv} , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 299.3701$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03714718$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0782342$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06922883$

and confined core properties:

$b = 540.00$

$d = 527.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 21.96205

cc (5A.5, TBDY) = 0.00298102

c = confinement factor = 1.0981

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04362424$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09187529$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08129972$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.17212448

$Mu = MR_c$ (4.14) = 2.1970E+008

$u = su$ (4.1) = 9.6917274E-006

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$

$l_b = 300.00$

$l_d = 1059.884$

Calculation of l_b ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = 150.00$

$n = 16.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$V_{r1} = V_{CoI}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{CoI0}$

$V_{CoI0} = 424229.688$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} + f \cdot V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/V_d = 4.00$

$Mu = 47.24078$

$Vu = 0.00016213$

$d = 0.8 \cdot h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$
 where:
 $V_{s1} = 223399.91$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 93083.296$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.75$
 $V_f ((11-3)-(11.4), ACI 440) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $a_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL \cdot t / NoDir = 1.016$
 $df_v = d$ (figure 11.2, ACI 440) = 557.00
 $ffe ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$
 $V_{Col0} = 424229.688$
 $knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\beta = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 47.24081$
 $V_u = 0.00016213$
 $d = 0.8 \cdot h = 480.00$
 $Nu = 8883.864$
 $Ag = 150000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$
 where:
 $V_{s1} = 223399.91$ is calculated for section web, with:
 $d = 480.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 150.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 93083.296$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 444.44$

$s = 150.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.75$
 $V_f((11-3)-(11.4), ACI\ 440) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe}((11-5), ACI\ 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 356502.845$
 $bw = 250.00$

 End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rdcS

Constant Properties

 Knowledge Factor, $\phi = 0.77$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$
 #####
 Max Height, $H_{max} = 600.00$
 Min Height, $H_{min} = 250.00$
 Max Width, $W_{max} = 600.00$
 Min Width, $W_{min} = 250.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.0981
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$

Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, Va = 0.00016213
EDGE -B-
Shear Force, Vb = -0.00016213
BOTH EDGES
Axial Force, F = -8883.864
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 4121.77
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1746.726
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 1545.664

Calculation of Shear Capacity ratio , $V_e/V_r = 0.62612363$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$
with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.9843E+008$
 $Mu_{1+} = 3.9843E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $Mu_{1-} = 2.1970E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.9843E+008$
 $Mu_{2+} = 3.9843E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination
 $Mu_{2-} = 2.1970E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.1848408E-005$$

$$Mu = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \phi_u = 0.0144353$$

$$\phi_{we}((5.4c), \text{TB DY}) = a_s e^* \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07473805$$

where $\phi_f = a_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.06888919$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.24098246$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) \cdot (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 \cdot esu_{1,nominal}$ ((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 $fsy_1 = f_s/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

```

with fs1 = fs = 299.3701
with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.28304984
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
with fs2 = fs = 299.3701
with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 299.3701
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.32281672
Mu = MRc (4.15) = 3.9843E+008
u = su (4.1) = 1.1848408E-005

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.28304984
lb = 300.00
lb = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

```

$db = 18.00$
Mean strength value of all re-bars: $f_y = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 9.6917274E-006$
 $\mu_1 = 2.1970E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$
 $fc = 20.00$
 $\alpha_1(5A.5, \text{TB DY}) = 0.002$
Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, \mu_c) = 0.0144353$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TB DY: $\mu = 0.0144353$
 μ_c ((5.4c), TB DY) = $\alpha_1 * \mu_{c0} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$
where $f = \alpha_1 * \mu_{c0} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TB DY) is modified as $\alpha_1 = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_1 = 0.24098246$$

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), $\mu_{c0} = 2t_f/b_w = 0.008128$

$$b_w = 250.00$$

effective stress from (A.35), $f_{fe} = 703.4155$

$$f_y = 0.06888919$$

Expression ((15B.6), TB DY) is modified as $\alpha_1 = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_1 = 0.24098246$$

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), $\mu_{c0} = 2t_f/b_w = 0.008128$

$$b_w = 250.00$$

effective stress from (A.35), $f_{fe} = 703.4155$

$$R = 40.00$$

Effective FRP thickness, $t_f = N L * t * \cos(b_1) = 1.016$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{f,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 105733.333 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00321875

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.00124738

sh1 = 0.00431097

ft1 = 359.2441

fy1 = 299.3701

su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb = 0.28304984

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb = 0.28304984

$\text{suv} = 0.4 \cdot \text{esuv_nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $\text{esuv_nominal} = 0.08$,
 considering characteristic value $\text{fsyv} = \text{fsv}/1.2$, from table 5.1, TBDY
 For calculation of esuv_nominal and yv , shv , ftv , fyv , it is considered
 characteristic value $\text{fsyv} = \text{fsv}/1.2$, from table 5.1, TBDY.
 y1 , sh1 , ft1 , fy1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE41-17.
 with $\text{fsv} = \text{fs} = 299.3701$
 with $\text{Esv} = \text{Es} = 200000.00$
 $1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.03714718$
 $2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.0782342$
 $\text{v} = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.06922883$
 and confined core properties:
 $\text{b} = 540.00$
 $\text{d} = 527.00$
 $\text{d}' = 13.00$
 $\text{fcc} (5A.2, \text{TBDY}) = 21.96205$
 $\text{cc} (5A.5, \text{TBDY}) = 0.00298102$
 $\text{c} = \text{confinement factor} = 1.0981$
 $1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.04362424$
 $2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.09187529$
 $\text{v} = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.08129972$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $\text{v} < \text{vs,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $\text{su} (4.9) = 0.17212448$
 $\text{Mu} = \text{MRc} (4.14) = 2.1970\text{E}+008$
 $\text{u} = \text{su} (4.1) = 9.6917274\text{E}-006$

Calculation of ratio lb/ld

Lap Length: $\text{lb}/\text{ld} = 0.28304984$
 $\text{lb} = 300.00$
 $\text{ld} = 1059.884$
 Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $\text{db} = 18.00$
 Mean strength value of all re-bars: $\text{fy} = 555.55$
 $\text{fc}' = 20.00$, but $\text{fc}'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $\text{t} = 1.00$
 $\text{s} = 0.80$
 $\text{e} = 1.00$
 $\text{cb} = 25.00$
 $\text{Ktr} = 2.61799$
 $\text{Atr} = \text{Min}(\text{Atr}_x, \text{Atr}_y) = 157.0796$
 where Atr_x , Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $\text{s} = 150.00$
 $\text{n} = 16.00$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $\text{u} = 1.1848408\text{E}-005$
 $\text{Mu} = 3.9843\text{E}+008$

with full section properties:

$\text{b} = 250.00$
 $\text{d} = 557.00$
 $\text{d}' = 43.00$
 $\text{v} = 0.0031899$
 $\text{N} = 8883.864$

$f_c = 20.00$
 $\alpha (5A.5, TBDY) = 0.002$
 Final value of α : $\alpha = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.0144353$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\alpha = 0.0144353$
 we ((5.4c), TBDY) = $\alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$
 where $f = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\alpha_f = 0.24098246$
 with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$
 $b_{\max} = 600.00$
 $h_{\max} = 600.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.008128$
 $b_w = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$f_y = 0.06888919$
 Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\alpha_f = 0.24098246$
 with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$
 $b_{\max} = 600.00$
 $h_{\max} = 600.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.008128$
 $b_w = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$
 Effective FRP thickness, $t_f = N_L * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_f = 0.015$
 $\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.21805635$
 The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.
 $A_{\text{conf,max}} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{\text{conf,min}} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max}}$ by a length equal to half the clear spacing between hoops.
 $A_{\text{noConf}} = 105733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).
 $\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.00321875$
 Expression ((5.4d), TBDY) for $\rho_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\rho_{sh,x}$ ((5.4d), TBDY) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$
 L_{stir} (Length of stirrups along Y) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$\rho_{sh,y}$ ((5.4d), TBDY) = $L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00321875$
 L_{stir} (Length of stirrups along X) = 1460.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 237500.00

$s = 150.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
 From ((5A.5), TBDY), TBDY: $\alpha_c = 0.00298102$
 α_c = confinement factor = 1.0981
 $y_1 = 0.00124738$
 $sh_1 = 0.00431097$
 $ft_1 = 359.2441$


```

fy1 = 299.3701
su1 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 0.28304984
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fs1 = fs = 299.3701
    with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/ld = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
    c = confinement factor = 1.0981
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
    2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
    v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is not satisfied
---->
v < vs,c - RHS eq.(4.5) is satisfied
---->
su (4.8) = 0.32281672

```

$$\begin{aligned} \mu &= M R_c (4.15) = 3.9843E+008 \\ u &= s_u (4.1) = 1.1848408E-005 \end{aligned}$$

Calculation of ratio l_b/l_d

$$\begin{aligned} \text{Lap Length: } l_b/l_d &= 0.28304984 \\ l_b &= 300.00 \\ l_d &= 1059.884 \end{aligned}$$

Calculation of l_b ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$\begin{aligned} &= 1 \\ d_b &= 18.00 \\ \text{Mean strength value of all re-bars: } f_y &= 555.55 \\ f_c' &= 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)} \\ t &= 1.00 \\ s &= 0.80 \\ e &= 1.00 \\ c_b &= 25.00 \\ K_{tr} &= 2.61799 \\ A_{tr} &= \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796 \\ &\text{where } A_{tr_x}, A_{tr_y} \text{ are the sum of the area of all stirrup legs along X and Y loxal axis} \\ s &= 150.00 \\ n &= 16.00 \end{aligned}$$

Calculation of μ_2 -

$$\begin{aligned} \text{Calculation of ultimate curvature } u &\text{ according to 4.1, Biskinis/Fardis 2013:} \\ u &= 9.6917274E-006 \\ \mu &= 2.1970E+008 \end{aligned}$$

with full section properties:

$$\begin{aligned} b &= 600.00 \\ d &= 557.00 \\ d' &= 43.00 \\ v &= 0.00132912 \\ N &= 8883.864 \\ f_c &= 20.00 \\ c_o \text{ (5A.5, TBDY)} &= 0.002 \\ \text{Final value of } c_u: c_u^* &= \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0144353 \\ \text{The Shear_factor is considered equal to 1 (pure moment strength)} \\ \text{From (5.4b), TBDY: } c_u &= 0.0144353 \\ w_e \text{ ((5.4c), TBDY)} &= a s_e * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805 \\ \text{where } f &= a f * p f * f_{fe} / f_{ce} \text{ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)} \end{aligned}$$

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p f = 2 t f / b w = 0.008128$$

$$b w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p f = 2 t f / b w = 0.008128$$

$$b w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_f = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$$fy_1 = 299.3701$$

$$su_1 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.28304984$$

$$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 299.3701$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00124738$$

$$sh_2 = 0.00431097$$

$$ft_2 = 359.2441$$

$$fy_2 = 299.3701$$

$$su_2 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$$

$$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_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 fs2 = fs = 299.3701
with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 299.3701
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
and confined core properties:
b = 540.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.17212448
Mu = MRc (4.14) = 2.1970E+008
u = su (4.1) = 9.6917274E-006

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00

```

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 424229.688$

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$

$V_{Col0} = 424229.688$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 47.23669$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 93083.296$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.75$

$V_{s2} = 223399.91$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.3125$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$

$V_{r2} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$

$V_{Col0} = 424229.688$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 47.23667$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 93083.296$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.75$

$V_{s2} = 223399.91$ is calculated for section flange, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.3125$

V_f ((11-3)-(11.4), ACI 440) = 293495.545

$f = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha, \theta)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:

total thickness per orientation, $tf_1 = NL \cdot t / NoDir = 1.016$

$df_v = d$ (figure 11.2, ACI 440) = 557.00

ffe ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$fe = 0.004$, from (11.6a), ACI 440

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
At local axis: 2
Integration Section: (b)
Section Type: rdcS

Constant Properties

Knowledge Factor, $\phi = 0.77$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $\epsilon_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -101614.073$
 Shear Force, $V_2 = 3536.316$
 Shear Force, $V_3 = -123.1168$
 Axial Force, $F = -9530.256$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{slt} = 0.00$
 -Compression: $A_{slc} = 4121.77$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten} = 1746.726$
 -Compression: $A_{sl,com} = 829.3805$
 -Middle: $A_{sl,mid} = 1545.664$
 Mean Diameter of Tension Reinforcement, $D_{bL} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $\phi_{u,R} = \phi_u = 0.03382254$
 $\phi_u = \phi_y + \phi_p = 0.04392538$

- Calculation of ϕ_y -

$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00192538$ ((4.29), Biskinis Phd))
 $M_y = 2.9338E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 825.3468
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$
 $factor = 0.30$
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9530.256$
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

$\phi_y = \text{Min}(\phi_{y,ten}, \phi_{y,com})$
 $\phi_{y,ten} = 4.0516275E-006$
 with ((10.1), ASCE 41-17) $\phi_y = \text{Min}(\phi_y, 1.25 * \phi_y * (l_b/d)^{2/3}) = 277.9106$
 $d = 557.00$
 $\phi_y = 0.38426988$
 $A = 0.02984605$
 $B = 0.01922829$
 with $pt = 0.01254381$
 $pc = 0.00595605$
 $pv = 0.01109992$
 $N = 9530.256$
 $b = 250.00$
 $\phi_y = 0.07719928$

```

y_comp = 8.1950430E-006
with fc* (12.3, (ACI 440)) = 20.42407
fc = 20.00
fl = 0.62098351
b = bmax = 600.00
h = hmax = 600.00
Ag = 237500.00
g = pt + pc + pv = 0.02959978
rc = 40.00
Ae/Ac = 0.21783041
Effective FRP thickness, tf = NL*t*cos(b1) = 1.016
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 21019.039
y = 0.38317351
A = 0.02940413
B = 0.01898202
with Es = 200000.00

```

Calculation of ratio lb/d

Lap Length: ld/d,min = 0.3538123

lb = 300.00

ld = 847.9072

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 444.44

fc' = 20.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 2.61799

Atr = Min(Atr_x, Atr_y) = 157.0796

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis

s = 150.00

n = 16.00

- Calculation of p -

From table 10-8: p = 0.042

with:

- Columns not controlled by inadequate development or splicing along the clear height because lb/d >= 1

shear control ratio $VyE/VCol0E = 0.62612363$

d = 557.00

s = 0.00

$t = Av/(bw*s) + 2*tf/bw*(ffe/fs) = Av*Lstir/(Ag*s) + 2*tf/bw*(ffe/fs) = 0.00$

Av = 78.53982, is the area of every stirrup

Lstir = 1460.00, is the total Length of all stirrups parallel to loading (shear) direction

The term $2*tf/bw*(ffe/fs)$ is implemented to account for FRP contribution

where $f = 2*tf/bw$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and ffe/fs normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

NUD = 9530.256

Ag = 237500.00

fcE = 20.00

fytE = fytE = 0.00

pl = Area_Tot_Long_Rein/(b*d) = 0.02959978

b = 250.00

d = 557.00

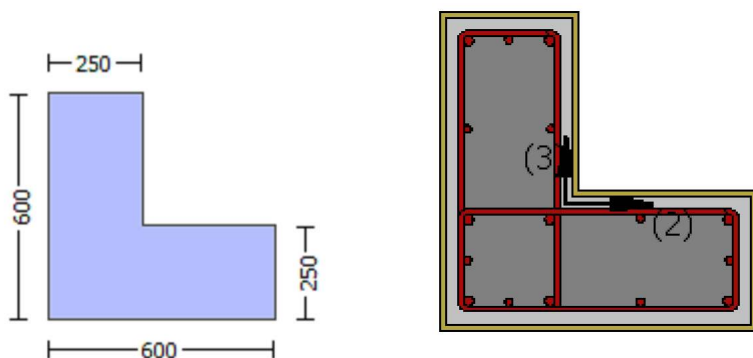
fcE = 20.00

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 2
Integration Section: (b)

Calculation No. 15

column C1, Floor 1
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Shear capacity VRd
Edge: End
Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3
Integration Section: (b)
Section Type: rdcs

Constant Properties

Knowledge Factor, $\gamma = 0.77$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Max Height, Hmax = 600.00
 Min Height, Hmin = 250.00
 Max Width, Wmax = 600.00
 Min Width, Wmin = 250.00
 Cover Thickness, c = 25.00
 Element Length, L = 3000.00
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length lo = lb = 300.00
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, t = 1.016
 Tensile Strength, ffu = 1055.00
 Tensile Modulus, Ef = 64828.00
 Elongation, efu = 0.01
 Number of directions, NoDir = 1
 Fiber orientations, bi: 0.00°
 Number of layers, NL = 1
 Radius of rounding corners, R = 40.00

Stepwise Properties

EDGE -A-
 Bending Moment, Ma = -266395.829
 Shear Force, Va = 123.1168
 EDGE -B-
 Bending Moment, Mb = -101614.073
 Shear Force, Vb = -123.1168
 BOTH EDGES
 Axial Force, F = -9530.256
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: Aslt = 0.00
 -Compression: Aslc = 4121.77
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: Asl,ten = 1746.726
 -Compression: Asl,com = 829.3805
 -Middle: Asl,mid = 1545.664
 Mean Diameter of Tension Reinforcement, DbL,ten = 17.71429

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity VR = *Vn = 339055.351
 Vn ((10.3), ASCE 41-17) = knl*VColO = 440331.624
 VCol = 440331.624
 knl = 1.00
 displacement_ductility_demand = 1.1629571E-005

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*VF'
 where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 fc' = 16.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 M/Vd = 2.00
 Mu = 101614.073
 Vu = 123.1168
 d = 0.8*h = 480.00
 Nu = 9530.256
 Ag = 150000.00
 From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 284837.734
 where:
 Vs1 = 201061.93 is calculated for section web, with:

$d = 480.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 150.00$
Vs1 is multiplied by Col1 = 1.00
 $s/d = 0.3125$
Vs2 = 83775.804 is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 150.00$
Vs2 is multiplied by Col2 = 1.00
 $s/d = 0.75$
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 293495.545$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
where a is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $a = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 557.00
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 318865.838$
 $b_w = 250.00$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END B -
for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 2.2391291\text{E-}008$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00192538$ ((4.29), Biskinis Phd))
 $M_y = 2.9338\text{E+}008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 825.3468
From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1921\text{E+}013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9530.256$
 $E_c \cdot I_g = 1.3974\text{E+}014$

Calculation of Yielding Moment M_y

Calculation of δ and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.0516275\text{E-}006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b/d)^{2/3}) = 277.9106$
 $d = 557.00$
 $y = 0.38426988$
 $A = 0.02984605$
 $B = 0.01922829$
with $p_t = 0.01254381$
 $p_c = 0.00595605$
 $p_v = 0.01109992$
 $N = 9530.256$
 $b = 250.00$

$\rho = 0.07719928$
 $y_{comp} = 8.1950430E-006$
 with f_c^* (12.3, (ACI 440)) = 20.42407
 $f_c = 20.00$
 $f_l = 0.62098351$
 $b = b_{max} = 600.00$
 $h = h_{max} = 600.00$
 $A_g = 237500.00$
 $g = p_t + p_c + p_v = 0.02959978$
 $r_c = 40.00$
 $A_e/A_c = 0.21783041$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.38317351$
 $A = 0.02940413$
 $B = 0.01898202$
 with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.3538123$

$l_b = 300.00$

$l_d = 847.9072$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.61799$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 150.00$

$n = 16.00$

End Of Calculation of Shear Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 16

column C1, Floor 1

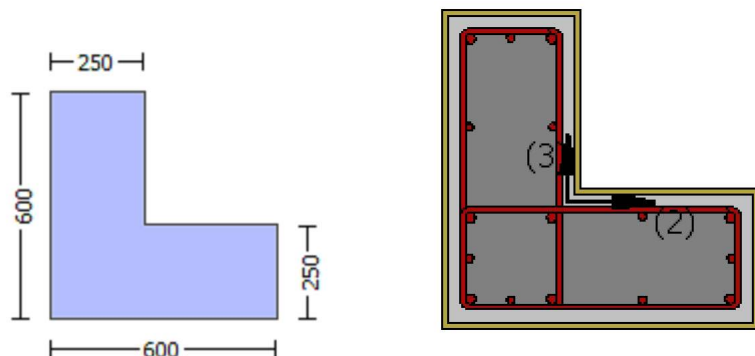
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

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, $\phi = 0.77$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, Va = 0.00016213
EDGE -B-
Shear Force, Vb = -0.00016213
BOTH EDGES
Axial Force, F = -8883.864
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 4121.77
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1746.726
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 1545.664

Calculation of Shear Capacity ratio , $V_e/V_r = 0.62612363$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$
with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.9843E+008$
 $Mu_{1+} = 3.9843E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $Mu_{1-} = 2.1970E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.9843E+008$
 $Mu_{2+} = 3.9843E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $Mu_{2-} = 2.1970E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 1.1848408E-005$$

$$Mu = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$c_o(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \phi_u = 0.0144353$$

$$\phi_{we}((5.4c), \text{TB DY}) = a_s e^* \phi_{sh, \min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07473805$$

where $\phi_f = a_f * \phi_{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.06888919$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$f_y = 0.06888919$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.24098246$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = N_L \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) \cdot (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 \cdot esu_1_{nominal}$ ((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 $fsy_1 = f_s/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

```

with fs1 = fs = 299.3701
with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb,min = 0.28304984
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
with fs2 = fs = 299.3701
with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/lb = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 299.3701
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.32281672
Mu = MRc (4.15) = 3.9843E+008
u = su (4.1) = 1.1848408E-005

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.28304984
lb = 300.00
lb = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

```


$db = 18.00$
Mean strength value of all re-bars: $f_y = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 9.6917274E-006$
 $\mu_1 = 2.1970E+008$

with full section properties:

$b = 600.00$
 $d = 557.00$
 $d' = 43.00$
 $v = 0.00132912$
 $N = 8883.864$
 $fc = 20.00$
 $\alpha_1(5A.5, \text{TB DY}) = 0.002$
Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, \mu_c) = 0.0144353$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TB DY: $\mu = 0.0144353$
 $\mu_e((5.4c), \text{TB DY}) = \alpha_1 * \mu_{min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$
where $f = \alpha_1 * \mu_{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TB DY) is modified as $\alpha_1 = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_1 = 0.24098246$$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

From EC8 A.4.4.3(6), $\mu_{pf} = 2t_f/b_w = 0.008128$

$$b_w = 250.00$$

effective stress from (A.35), $f_{fe} = 703.4155$

$$f_y = 0.06888919$$

Expression ((15B.6), TB DY) is modified as $\alpha_1 = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_1 = 0.24098246$$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

From EC8 A.4.4.3(6), $\mu_{pf} = 2t_f/b_w = 0.008128$

$$b_w = 250.00$$

effective stress from (A.35), $f_{fe} = 703.4155$

$$R = 40.00$$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{f,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 169100.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

Aconf,min = 98400.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max by a length equal to half the clear spacing between hoops.

AnoConf = 105733.333 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min = Min(psh,x , psh,y) = 0.00321875

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875

Lstir (Length of stirrups along Y) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00321875

Lstir (Length of stirrups along X) = 1460.00

Astir (stirrups area) = 78.53982

Asec (section area) = 237500.00

s = 150.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00298102

c = confinement factor = 1.0981

y1 = 0.00124738

sh1 = 0.00431097

ft1 = 359.2441

fy1 = 299.3701

su1 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb = 0.28304984

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 299.3701

with Es1 = Es = 200000.00

y2 = 0.00124738

sh2 = 0.00431097

ft2 = 359.2441

fy2 = 299.3701

su2 = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.28304984

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE41-17.

with fs2 = fs = 299.3701

with Es2 = Es = 200000.00

yv = 0.00124738

shv = 0.00431097

ftv = 359.2441

fyv = 299.3701

suv = 0.00446911

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb = 0.28304984

$\text{suv} = 0.4 \cdot \text{esuv_nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $\text{esuv_nominal} = 0.08$,
 considering characteristic value $\text{fsyv} = \text{fsv}/1.2$, from table 5.1, TBDY
 For calculation of esuv_nominal and yv , shv , ftv , fyv , it is considered
 characteristic value $\text{fsyv} = \text{fsv}/1.2$, from table 5.1, TBDY.
 y1 , sh1 , ft1 , fy1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE41-17.
 with $\text{fsv} = \text{fs} = 299.3701$
 with $\text{Esv} = \text{Es} = 200000.00$
 $1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.03714718$
 $2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.0782342$
 $\text{v} = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.06922883$
 and confined core properties:
 $\text{b} = 540.00$
 $\text{d} = 527.00$
 $\text{d}' = 13.00$
 $\text{fcc} (5A.2, \text{TBDY}) = 21.96205$
 $\text{cc} (5A.5, \text{TBDY}) = 0.00298102$
 $\text{c} = \text{confinement factor} = 1.0981$
 $1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.04362424$
 $2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.09187529$
 $\text{v} = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.08129972$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $\text{v} < \text{vs,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $\text{su} (4.9) = 0.17212448$
 $\text{Mu} = \text{MRc} (4.14) = 2.1970\text{E}+008$
 $\text{u} = \text{su} (4.1) = 9.6917274\text{E}-006$

Calculation of ratio lb/ld

Lap Length: $\text{lb}/\text{ld} = 0.28304984$
 $\text{lb} = 300.00$
 $\text{ld} = 1059.884$
 Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $\text{db} = 18.00$
 Mean strength value of all re-bars: $\text{fy} = 555.55$
 $\text{fc}' = 20.00$, but $\text{fc}'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $\text{t} = 1.00$
 $\text{s} = 0.80$
 $\text{e} = 1.00$
 $\text{cb} = 25.00$
 $\text{Ktr} = 2.61799$
 $\text{Atr} = \text{Min}(\text{Atr}_x, \text{Atr}_y) = 157.0796$
 where Atr_x , Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $\text{s} = 150.00$
 $\text{n} = 16.00$

Calculation of Mu_{2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $\text{u} = 1.1848408\text{E}-005$
 $\text{Mu} = 3.9843\text{E}+008$

with full section properties:

$\text{b} = 250.00$
 $\text{d} = 557.00$
 $\text{d}' = 43.00$
 $\text{v} = 0.0031899$
 $\text{N} = 8883.864$

$$f_c = 20.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.0144353$$

$$\text{we ((5.4c), TBDY)} = a_s e * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

```

fy1 = 299.3701
su1 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.28304984
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fs1 = fs = 299.3701
    with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
    c = confinement factor = 1.0981
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
    2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
    v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is not satisfied
---->
v < vs,c - RHS eq.(4.5) is satisfied
---->
su (4.8) = 0.32281672

```

$$\begin{aligned} \mu &= MRC(4.15) = 3.9843E+008 \\ u &= s_u(4.1) = 1.1848408E-005 \end{aligned}$$

Calculation of ratio l_b/l_d

$$\begin{aligned} \text{Lap Length: } l_b/l_d &= 0.28304984 \\ l_b &= 300.00 \\ l_d &= 1059.884 \end{aligned}$$

Calculation of l_b ,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$\begin{aligned} &= 1 \\ db &= 18.00 \\ \text{Mean strength value of all re-bars: } f_y &= 555.55 \\ f'_c &= 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)} \\ t &= 1.00 \\ s &= 0.80 \\ e &= 1.00 \\ cb &= 25.00 \\ K_{tr} &= 2.61799 \\ A_{tr} &= \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796 \\ &\text{where } A_{tr_x}, A_{tr_y} \text{ are the sum of the area of all stirrup legs along X and Y loxal axis} \\ s &= 150.00 \\ n &= 16.00 \end{aligned}$$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\begin{aligned} u &= 9.6917274E-006 \\ \mu &= 2.1970E+008 \end{aligned}$$

with full section properties:

$$\begin{aligned} b &= 600.00 \\ d &= 557.00 \\ d' &= 43.00 \\ v &= 0.00132912 \\ N &= 8883.864 \\ f_c &= 20.00 \\ c_o(5A.5, TBDY) &= 0.002 \\ \text{Final value of } c_u: c_u^* &= \text{shear_factor} * \text{Max}(c_u, c_c) = 0.0144353 \\ &\text{The Shear_factor is considered equal to 1 (pure moment strength)} \\ \text{From (5.4b), TBDY: } c_u &= 0.0144353 \\ w_e((5.4c), TBDY) &= a_s e * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07473805 \\ &\text{where } f = a_f * p_f * f_{fe} / f_{ce} \text{ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)} \end{aligned}$$

$$f_x = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 57233.333$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$f_y = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 600.00$$

$$h_{\max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_f = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$s = 150.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y_1 = 0.00124738$$

$$sh_1 = 0.00431097$$

$$ft_1 = 359.2441$$

$$fy_1 = 299.3701$$

$$su_1 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.28304984$$

$$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 299.3701$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00124738$$

$$sh_2 = 0.00431097$$

$$ft_2 = 359.2441$$

$$fy_2 = 299.3701$$

$$su_2 = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$$

$$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_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 fs2 = fs = 299.3701
with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
lo/lou,min = lb/ld = 0.28304984
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 299.3701
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
and confined core properties:
b = 540.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.17212448
Mu = MRc (4.14) = 2.1970E+008
u = su (4.1) = 9.6917274E-006

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00

```

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 424229.688

Calculation of Shear Strength at edge 1, $V_{r1} = 424229.688$

$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$

$V_{Col0} = 424229.688$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 47.24078$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 223399.91$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.3125$

$V_{s2} = 93083.296$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.75$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 293495.545$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 424229.688$

$V_{r2} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$

$V_{Col0} = 424229.688$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 47.24081$

$V_u = 0.00016213$

$d = 0.8 * h = 480.00$

$N_u = 8883.864$

$A_g = 150000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 316483.206$

where:

$V_{s1} = 223399.91$ is calculated for section web, with:

$d = 480.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.3125$

$V_{s2} = 93083.296$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 150.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.75$

$V_f ((11-3)-(11.4), ACI 440) = 293495.545$

$f = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $a_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 557.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 356502.845$

$bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rdcS

Constant Properties

Knowledge Factor, $\phi = 0.77$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 600.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 600.00$

Min Width, $W_{min} = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.0981

Element Length, $L = 3000.00$

Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $\epsilon_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $b_i = 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
 EDGE -A-
 Shear Force, $V_a = 0.00016213$
 EDGE -B-
 Shear Force, $V_b = -0.00016213$
 BOTH EDGES
 Axial Force, $F = -8883.864$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 4121.77$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{t,ten} = 1746.726$
 -Compression: $As_{l,com} = 829.3805$
 -Middle: $As_{l,mid} = 1545.664$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.62612363$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 265620.233$
 with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 3.9843E+008$
 $Mu_{1+} = 3.9843E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $Mu_{1-} = 2.1970E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 3.9843E+008$
 $Mu_{2+} = 3.9843E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination
 $Mu_{2-} = 2.1970E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.1848408E-005$
 $M_u = 3.9843E+008$

with full section properties:

$b = 250.00$
 $d = 557.00$
 $d' = 43.00$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$co (5A.5, TBDY) = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.0144353$$

$$\text{we ((5.4c), TBDY) } = ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07473805$$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$$af = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf / bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff_e = 703.4155$$

$$fy = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$$af = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf / bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff_e = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL * t * \cos(b1) = 1.016$$

$$fu_f = 1055.00$$

$$Ef = 64828.00$$

$$u_f = 0.015$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00321875$$

Expression ((5.4d), TBDY) for psh_{min} has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along Y}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$psh_y ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} (\text{Length of stirrups along X}) = 1460.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 237500.00$$

$$s = 150.00$$

$$fy_{we} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), } cc = 0.00298102$$

$$c = \text{confinement factor} = 1.0981$$

$$y1 = 0.00124738$$

```

sh1 = 0.00431097
ft1 = 359.2441
fy1 = 299.3701
su1 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.28304984
    su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu1_nominal = 0.08,
    For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
    characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fs1 = fs = 299.3701
    with Es1 = Es = 200000.00
y2 = 0.00124738
sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lou,min = lb/lb = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.18776209
2 = Asl,com/(b*d)*(fs2/fc) = 0.08915322
v = Asl,mid/(b*d)*(fsv/fc) = 0.16614919
and confined core properties:
b = 190.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
    c = confinement factor = 1.0981
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
    2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
    v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied

```

--->

$$su(4.8) = 0.32281672$$

$$Mu = MRc(4.15) = 3.9843E+008$$

$$u = su(4.1) = 1.1848408E-005$$

Calculation of ratio lb/ld

$$\text{Lap Length: } lb/ld = 0.28304984$$

$$lb = 300.00$$

$$ld = 1059.884$$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$fc' = 20.00, \text{ but } fc'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 2.61799$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$$s = 150.00$$

$$n = 16.00$$

Calculation of Mu_1 -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 9.6917274E-006$$

$$Mu = 2.1970E+008$$

with full section properties:

$$b = 600.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.00132912$$

$$N = 8883.864$$

$$fc = 20.00$$

$$co(5A.5, TBDY) = 0.002$$

$$\text{Final value of } cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.0144353$$

$$\text{we ((5.4c), TBDY) } = ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07473805$$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$$af = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff_e = 703.4155$$

$$fy = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$$af = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008128$$

bw = 250.00
effective stress from (A.35), $f_{fe} = 703.4155$

R = 40.00
Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.21805635$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00321875$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

s = 150.00

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y_1 = 0.00124738$

$sh_1 = 0.00431097$

$ft_1 = 359.2441$

$fy_1 = 299.3701$

$su_1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.28304984$

$su_1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 299.3701$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00124738$

$sh_2 = 0.00431097$

$ft_2 = 359.2441$

$fy_2 = 299.3701$

$su_2 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.28304984$

$su_2 = 0.4 \cdot esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered

characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 299.3701$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00124738$
 $sh_v = 0.00431097$
 $ft_v = 359.2441$
 $fy_v = 299.3701$
 $suv = 0.00446911$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.28304984$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$
 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.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 299.3701$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.03714718$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0782342$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06922883$
 and confined core properties:
 $b = 540.00$
 $d = 527.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 21.96205$
 $cc (5A.5, TBDY) = 0.00298102$
 $c = \text{confinement factor} = 1.0981$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.04362424$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09187529$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08129972$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.17212448$
 $Mu = MR_c (4.14) = 2.1970E+008$
 $u = su (4.1) = 9.6917274E-006$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.28304984$
 $l_b = 300.00$
 $l_d = 1059.884$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 2.61799$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Mu_{2+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.1848408E-005$$

$$\mu = 3.9843E+008$$

with full section properties:

$$b = 250.00$$

$$d = 557.00$$

$$d' = 43.00$$

$$v = 0.0031899$$

$$N = 8883.864$$

$$f_c = 20.00$$

$$\phi_c \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \phi_u: \phi_u = \text{shear_factor} * \text{Max}(\phi_c, \phi_c) = 0.0144353$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.0144353$$

$$\phi_{we} \text{ ((5.4c), TBDY)} = a_s * \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07473805$$

where $\phi_{fx} = a_s * \phi_{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 57233.333$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{pf} = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$\phi_{fy} = 0.06888919$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.24098246$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 600.00$$

$$h_{max} = 600.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_{pf} = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.21805635$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00321875$$

Expression ((5.4d), TBDY) for $\phi_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\phi_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00321875$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1460.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 237500.00$$

$$\text{psh,y ((5.4d), TBDY)} = \text{Lstir} \cdot \text{Astir} / (\text{Asec} \cdot \text{s}) = 0.00321875$$

$$\text{Lstir (Length of stirrups along X)} = 1460.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 237500.00$$

$$\text{s} = 150.00$$

$$\text{fywe} = 555.55$$

$$\text{fce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: cc} = 0.00298102$$

$$\text{c} = \text{confinement factor} = 1.0981$$

$$\text{y1} = 0.00124738$$

$$\text{sh1} = 0.00431097$$

$$\text{ft1} = 359.2441$$

$$\text{fy1} = 299.3701$$

$$\text{su1} = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/lb} = 0.28304984$$

$$\text{su1} = 0.4 \cdot \text{esu1_nominal} ((5.5), \text{TBDY}) = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fs1} = \text{fs} = 299.3701$$

$$\text{with Es1} = \text{Es} = 200000.00$$

$$\text{y2} = 0.00124738$$

$$\text{sh2} = 0.00431097$$

$$\text{ft2} = 359.2441$$

$$\text{fy2} = 299.3701$$

$$\text{su2} = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/lb,min} = 0.28304984$$

$$\text{su2} = 0.4 \cdot \text{esu2_nominal} ((5.5), \text{TBDY}) = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fs2} = \text{fs} = 299.3701$$

$$\text{with Es2} = \text{Es} = 200000.00$$

$$\text{yv} = 0.00124738$$

$$\text{shv} = 0.00431097$$

$$\text{ftv} = 359.2441$$

$$\text{fyv} = 299.3701$$

$$\text{suv} = 0.00446911$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/lb} = 0.28304984$$

$$\text{suv} = 0.4 \cdot \text{esuv_nominal} ((5.5), \text{TBDY}) = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fsv} = \text{fs} = 299.3701$$

$$\text{with Esv} = \text{Es} = 200000.00$$

$$1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.18776209$$

$$2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.08915322$$

$$\text{v} = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.16614919$$

and confined core properties:

$$\text{b} = 190.00$$

$$\text{d} = 527.00$$

$$\text{d}' = 13.00$$

$$\text{fcc (5A.2, TBDY)} = 21.96205$$

```

cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.26111925
2 = Asl,com/(b*d)*(fs2/fc) = 0.12398468
v = Asl,mid/(b*d)*(fsv/fc) = 0.23106236
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is not satisfied
--->
v < vs,c - RHS eq.(4.5) is satisfied
--->
su (4.8) = 0.32281672
Mu = MRc (4.15) = 3.9843E+008
u = su (4.1) = 1.1848408E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00

```

Calculation of Mu2-

```

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 9.6917274E-006
Mu = 2.1970E+008

```

with full section properties:

```

b = 600.00
d = 557.00
d' = 43.00
v = 0.00132912
N = 8883.864
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.0144353
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.0144353
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.07473805
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
fx = 0.06888919
Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)
af = 0.24098246
with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 57233.333
bmax = 600.00
hmax = 600.00

```

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $ff,e = 703.4155$

$fy = 0.06888919$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.24098246$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 600.00$

$h_{max} = 600.00$

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff,e = 703.4155$

$R = 40.00$

Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$

$fu,f = 1055.00$

$Ef = 64828.00$

$u,f = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.21805635$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 169100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 98400.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max}$ by a length equal to half the clear spacing between hoops.

$A_{noConf} = 105733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh,min = \text{Min}(psh,x, psh,y) = 0.00321875$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x \text{ ((5.4d), TBDY)} = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$

L_{stir} (Length of stirrups along Y) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$psh,y \text{ ((5.4d), TBDY)} = L_{stir}*A_{stir}/(A_{sec}*s) = 0.00321875$

L_{stir} (Length of stirrups along X) = 1460.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 237500.00

$s = 150.00$

$fywe = 555.55$

$fce = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00298102$

c = confinement factor = 1.0981

$y1 = 0.00124738$

$sh1 = 0.00431097$

$ft1 = 359.2441$

$fy1 = 299.3701$

$su1 = 0.00446911$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{u,min} = lb/l_d = 0.28304984$

$su1 = 0.4*esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 299.3701$

with $Es1 = Es = 200000.00$

$y2 = 0.00124738$

```

sh2 = 0.00431097
ft2 = 359.2441
fy2 = 299.3701
su2 = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/lb,min = 0.28304984
    su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esu2_nominal = 0.08,
    For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
    characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fs2 = fs = 299.3701
    with Es2 = Es = 200000.00
yv = 0.00124738
shv = 0.00431097
ftv = 359.2441
fyv = 299.3701
suv = 0.00446911
    using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
    and also multiplied by the shear_factor according to 15.7.1.4, with
    Shear_factor = 1.00
    lo/lo,min = lb/ld = 0.28304984
    suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
    From table 5A.1, TBDY: esuv_nominal = 0.08,
    considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
    For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
    characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
    y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 299.3701
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.03714718
2 = Asl,com/(b*d)*(fs2/fc) = 0.0782342
v = Asl,mid/(b*d)*(fsv/fc) = 0.06922883
and confined core properties:
b = 540.00
d = 527.00
d' = 13.00
fcc (5A.2, TBDY) = 21.96205
cc (5A.5, TBDY) = 0.00298102
c = confinement factor = 1.0981
1 = Asl,ten/(b*d)*(fs1/fc) = 0.04362424
2 = Asl,com/(b*d)*(fs2/fc) = 0.09187529
v = Asl,mid/(b*d)*(fsv/fc) = 0.08129972
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.17212448
Mu = MRc (4.14) = 2.1970E+008
u = su (4.1) = 9.6917274E-006

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.28304984
lb = 300.00
ld = 1059.884
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80

```

$e = 1.00$
 $cb = 25.00$
 $Ktr = 2.61799$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 150.00$
 $n = 16.00$

Calculation of Shear Strength $Vr = \text{Min}(Vr1, Vr2) = 424229.688$

Calculation of Shear Strength at edge 1, $Vr1 = 424229.688$

$Vr1 = VCol$ ((10.3), ASCE 41-17) = $knl * VCol0$

$VCol0 = 424229.688$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' Vs ' is replaced by ' $Vs + f * Vf$ '
 where Vf is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

$fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 47.23669$

$Vu = 0.00016213$

$d = 0.8 * h = 480.00$

$Nu = 8883.864$

$Ag = 150000.00$

From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 316483.206$

where:

$Vs1 = 93083.296$ is calculated for section web, with:

$d = 200.00$

$Av = 157079.633$

$fy = 444.44$

$s = 150.00$

$Vs1$ is multiplied by $Col1 = 1.00$

$s/d = 0.75$

$Vs2 = 223399.91$ is calculated for section flange, with:

$d = 480.00$

$Av = 157079.633$

$fy = 444.44$

$s = 150.00$

$Vs2$ is multiplied by $Col2 = 1.00$

$s/d = 0.3125$

Vf ((11-3)-(11.4), ACI 440) = 293495.545

$f = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc) \sin \alpha$ which is more a generalised expression,
 where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $Vf(\alpha)$, 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: $\alpha = b1 + 90^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, \alpha)|, |Vf(-45, \alpha)|)$, with:

total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 557.00

ffe ((11-5), ACI 440) = 259.312

$Ef = 64828.00$

$fe = 0.004$, from (11.6a), ACI 440

with $fu = 0.01$

From (11-11), ACI 440: $Vs + Vf \leq 356502.845$

$bw = 250.00$

Calculation of Shear Strength at edge 2, $Vr2 = 424229.688$

$Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl * VCol0$

$VCol0 = 424229.688$

knl = 1 (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

fc' = 20.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 47.23667

Vu = 0.00016213

d = 0.8*h = 480.00

Nu = 8883.864

Ag = 150000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 316483.206

where:

Vs1 = 93083.296 is calculated for section web, with:

d = 200.00

Av = 157079.633

fy = 444.44

s = 150.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.75

Vs2 = 223399.91 is calculated for section flange, with:

d = 480.00

Av = 157079.633

fy = 444.44

s = 150.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.3125

Vf ((11-3)-(11.4), ACI 440) = 293495.545

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(α), is implemented for every different fiber orientation ai,
as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, α)|, |Vf(-45, α)|), with:

total thickness per orientation, tf1 = NL*t/NoDir = 1.016

dfv = d (figure 11.2, ACI 440) = 557.00

ffe ((11-5), ACI 440) = 259.312

Ef = 64828.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.01

From (11-11), ACI 440: Vs + Vf <= 356502.845

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column LC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1
At local axis: 3

Integration Section: (b)

Section Type: rdcs

Constant Properties

Knowledge Factor, $\phi = 0.77$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00

Existing material of Secondary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 600.00$
Min Height, $H_{min} = 250.00$
Max Width, $W_{max} = 600.00$
Min Width, $W_{min} = 250.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $\epsilon_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 136240.323$
Shear Force, $V_2 = 3536.316$
Shear Force, $V_3 = -123.1168$
Axial Force, $F = -9530.256$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 4121.77$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 1746.726$
-Compression: $A_{st,com} = 829.3805$
-Middle: $A_{st,mid} = 1545.664$
Mean Diameter of Tension Reinforcement, $D_{bL} = 17.71429$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $\phi_{u,R} = \phi_u = 0.03287888$
 $\phi_u = \phi_y + \phi_p = 0.04269984$

- Calculation of ϕ_y -

$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00069984$ ((4.29), Biskinis Phd))
 $M_y = 2.9338E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1921E+013$
factor = 0.30
 $A_g = 237500.00$
 $f_c' = 20.00$
 $N = 9530.256$
 $E_c * I_g = 1.3974E+014$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

```

y = Min( y_ten, y_com)
y_ten = 4.0516275E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^ 2/3) = 277.9106
d = 557.00
y = 0.38426988
A = 0.02984605
B = 0.01922829
with pt = 0.01254381
pc = 0.00595605
pv = 0.01109992
N = 9530.256
b = 250.00
" = 0.07719928
y_comp = 8.1950430E-006
with fc* (12.3, (ACI 440)) = 20.42407
fc = 20.00
fl = 0.62098351
b = bmax = 600.00
h = hmax = 600.00
Ag = 237500.00
g = pt + pc + pv = 0.02959978
rc = 40.00
Ae/Ac = 0.21783041
Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 21019.039
y = 0.38317351
A = 0.02940413
B = 0.01898202
with Es = 200000.00

```

Calculation of ratio lb/d

```

Lap Length: ld/d,min = 0.3538123
lb = 300.00
ld = 847.9072
Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 444.44
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 2.61799
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 150.00
n = 16.00

```

- Calculation of p -

From table 10-8: p = 0.042

with:

- Columns not controlled by inadequate development or splicing along the clear height because lb/d >= 1

shear control ratio $V_yE/V_{ColOE} = 0.62612363$

d = 557.00

s = 0.00

$t = A_v/(b_w*s) + 2*tf/b_w*(ffe/fs) = A_v*Lstir/(Ag*s) + 2*tf/b_w*(ffe/fs) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$Lstir = 1460.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ 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 = 9530.256

Ag = 237500.00

$f_{cE} = 20.00$

$f_{yE} = f_{yIE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.02959978$

b = 250.00

d = 557.00

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column LC1 of floor 1

At local axis: 3

Integration Section: (b)
