

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

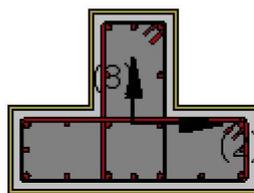
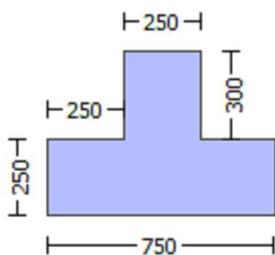
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 23025.204$

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, $f_c = f_{cm} = 24.00$

Existing material: Steel Strength, $f_s = f_{sm} = 525.00$

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Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $Ecc = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{o,min} = l_b/l_d \geq 1$)

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, $M_a = -9.6610E+006$

Shear Force, $V_a = -3183.231$

EDGE -B-

Bending Moment, $M_b = 108875.895$

Shear Force, $V_b = 3183.231$

BOTH EDGES

Axial Force, $F = -10230.902$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{st,ten} = 1231.504$

-Compression: $A_{st,com} = 1231.504$

-Middle: $A_{st,mid} = 2689.203$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 474332.66$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{Col} = 474332.66$

$V_{Col} = 474332.66$

$k_n = 1.00$

$displacement_ductility_demand = 0.00627177$

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 $f'_c \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$
 $\mu_u = 9.6610E+006$
 $V_u = 3183.231$
 $d = 0.8 \cdot h = 600.00$
 $N_u = 10230.902$
 $A_g = 187500.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 527787.566$
 where:
 $V_{s1} = 131946.891$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 395840.674$ is calculated for section flange, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.16666667$
 $V_f ((11-3)-(11.4), ACI 440) = 372533.843$
 $f = 0.95$, 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: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 707.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 398582.298$
 $b_w = 250.00$

displacement ductility demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 6.5656366E-005$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.01046855$ ((4.29), Biskinis Phd)
 $M_y = 6.5616E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3034.966
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 6.3409E+013$
 factor = 0.30
 $A_g = 262500.00$
 $f_c' = 24.00$
 $N = 10230.902$
 $E_c \cdot I_g = 2.1136E+014$

Calculation of Yielding Moment M_y

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

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 5.4983477E-006$
 with $f_y = 525.00$

d = 707.00
y = 0.32472963
A = 0.02925997
B = 0.01557156
with pt = 0.00696749
pc = 0.00696749
pv = 0.01521473
N = 10230.902
b = 250.00
" = 0.06082037
y_comp = 8.2387023E-006
with fc* (12.3, (ACI 440)) = 24.16756
fc = 24.00
fl = 0.56655003
b = bmax = 750.00
h = hmax = 550.00
Ag = 262500.00
g = pt + pc + pv = 0.02914971
rc = 40.00
Ae/Ac = 0.17542991
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 = 23025.204
y = 0.32435731
A = 0.02899653
B = 0.01546131
with Es = 200000.00

Calculation of ratio lb/ld

Adequate Lap Length: lb/ld >= 1

End Of Calculation of Shear Capacity for element: column TC1 of floor 1
At local axis: 2
Integration Section: (a)

Calculation No. 2

column C1, Floor 1

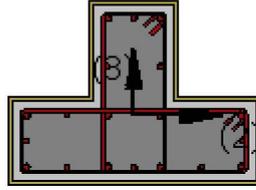
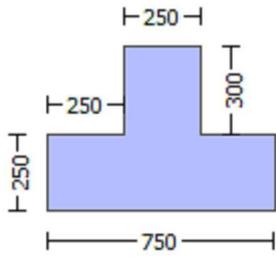
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 23025.204$
 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, $f_s = 1.25 \cdot f_{sm} = 656.25$

 Max Height, $H_{max} = 550.00$
 Min Height, $H_{min} = 250.00$
 Max Width, $W_{max} = 750.00$
 Min Width, $W_{min} = 250.00$
 Eccentricity, $Ecc = 250.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.30771
 Element Length, $L = 3000.00$

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

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, $V_a = 0.00020794$
 EDGE -B-

Shear Force, $V_b = -0.00020794$

BOTH EDGES

Axial Force, $F = -9867.325$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{st,ten} = 2261.947$

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

-Middle: $A_{sc,mid} = 2060.885$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.51499$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 645516.591$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 9.6827E+008$

$M_{u1+} = 9.6827E+008$, 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

$M_{u1-} = 8.4161E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 9.6827E+008$

$M_{u2+} = 9.6827E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 8.4161E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

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

$\phi_u = 2.0901588E-005$

$M_u = 9.6827E+008$

with full section properties:

$b = 250.00$

$d = 507.00$

$d' = 43.00$

$v = 0.0032437$

$N = 9867.325$

$f_c = 24.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01464812$

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

From (5.4b), TBDY: $\phi_{cu} = 0.01464812$

where ϕ_{cu} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07767542$

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

$\phi_{fx} = 0.03787432$

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

$\alpha_{f} = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$

$b_{max} = 750.00$

$h_{max} = 550.00$

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

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 748.2496$

$\phi_{fy} = 0.03787432$

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

$\alpha_{f} = 0.14946032$

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

$b_{max} = 750.00$

hmax = 550.00
From EC8 A.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 748.2496$

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

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$
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.
 $A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{\text{conf,min}} = 137025.00$ 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.
 $A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$
 L_{stir} (Length of stirrups along Y) = 1760.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 262500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$
 L_{stir} (Length of stirrups along X) = 1360.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 262500.00

s = 100.00
 $f_{ywe} = 656.25$
 $f_{ce} = 24.00$
From ((5.A5), TBDY), TBDY: $cc = 0.0050771$
c = confinement factor = 1.30771

$y1 = 0.0025$
 $sh1 = 0.008$
 $ft1 = 787.50$
 $fy1 = 656.25$
 $su1 = 0.032$

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

$l_o/l_{o,min} = l_b/l_d = 1.00$

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

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

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

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

with $fs1 = fs = 656.25$

with $Es1 = Es = 200000.00$

$y2 = 0.0025$
 $sh2 = 0.008$
 $ft2 = 787.50$
 $fy2 = 656.25$
 $su2 = 0.032$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

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

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

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

characteristic value $f_{s2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $f_{s2} = f_s = 656.25$
with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $f_{y_v} = 656.25$
 $s_{u_v} = 0.032$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $s_{u_v} = 0.4 \cdot e_{s_{u_v,nominal}} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $e_{s_{u_v,nominal}} = 0.08$,
considering characteristic value $f_{s_{y_v}} = f_{s_{y_v}}/1.2$, from table 5.1, TBDY
For calculation of $e_{s_{u_v,nominal}}$ and y_v, sh_v, ft_v, f_{y_v} , it is considered
characteristic value $f_{s_{y_v}} = f_{s_{y_v}}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $f_{s_v} = f_s = 656.25$
with $E_{s_v} = E_s = 200000.00$
 $1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.48796927$
 $2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.17892207$
 $v = A_{s1,mid}/(b \cdot d) \cdot (f_{s_v}/f_c) = 0.44459423$
and confined core properties:
 $b = 190.00$
 $d = 477.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.68244627$
 $2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.2502303$
 $v = A_{s1,mid}/(b \cdot d) \cdot (f_{s_v}/f_c) = 0.62178438$
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 not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
 $v < s_{y1}$ - LHS eq.(4.7) is not satisfied
--->
 $v < v_{c,y1}$ - RHS eq.(4.6) is satisfied
--->
 $c_u (4.10) = 0.43574957$
 $M_{Rc} (4.17) = 8.0482E+008$
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
- $N, 1, 2, v$ normalised to $b_o \cdot d_o$, instead of $b \cdot d$
- f_{cc}, cc parameters of confined concrete, f_{cc}, cc , used in lieu of f_c, e_{cu}
--->
Subcase: Rupture of tension steel
--->
 $v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied
--->
 $v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->

New Subcase: Failure of compression zone

--->

$v^* < v^*c,y2$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*c,y1$ - RHS eq.(4.6) is satisfied

--->

*cu (4.10) = 0.5092345

M_{Ro} (4.17) = 9.6827E+008

--->

u = cu (4.2) = 2.0901588E-005

Mu = M_{Ro}

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

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

u = 7.5354574E-005

Mu = 8.4161E+008

with full section properties:

b = 750.00

d = 507.00

d' = 43.00

v = 0.00108123

N = 9867.325

f_c = 24.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01464812

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

From (5.4b), TBDY: cu = 0.01464812

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.07767542

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

fx = 0.03787432

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

af = 0.14946032

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 39233.333

bmax = 750.00

hmax = 550.00

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

bw = 250.00

effective stress from (A.35), ff,e = 748.2496

fy = 0.03787432

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

af = 0.14946032

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 0.00

bmax = 750.00

hmax = 550.00

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

bw = 250.00

effective stress from (A.35), ff,e = 748.2496

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-A_{noConf})/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.35771528

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.

$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

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

$lo/lou,min = lb/l_d = 1.00$

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

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

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

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

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

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

$lo/lou,min = lb/l_{b,min} = 1.00$

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

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

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

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

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$su_v = 0.032$

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

Shear_factor = 1.00

lo/lou,min = lb/d = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.05964069

2 = Asl,com/(b*d)*(fs2/fc) = 0.16265642

v = Asl,mid/(b*d)*(fsv/fc) = 0.14819808

and confined core properties:

b = 690.00

d = 477.00

d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

1 = Asl,ten/(b*d)*(fs1/fc) = 0.068904

2 = Asl,com/(b*d)*(fs2/fc) = 0.18791999

v = Asl,mid/(b*d)*(fsv/fc) = 0.17121599

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) = 0.16240824

Mu = MRc (4.15) = 8.4161E+008

u = su (4.1) = 7.5354574E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

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

u = 2.0901588E-005

Mu = 9.6827E+008

with full section properties:

b = 250.00

d = 507.00

d' = 43.00

v = 0.0032437

N = 9867.325

fc = 24.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01464812

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

From (5.4b), TBDY: cu = 0.01464812

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.07767542

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

fx = 0.03787432

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

af = 0.14946032

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 39233.333

bmax = 750.00
hmax = 550.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 748.2496$

 $fy = 0.03787432$
Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$
 $af = 0.14946032$
with Unconfined area = $((bmax-2R)^2 + (hmax-2R)^2)/3 = 0.00$
bmax = 750.00
hmax = 550.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 748.2496$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
 $fu,f = 1055.00$
 $Ef = 64828.00$
 $u,f = 0.015$
 $ase = \text{Max}(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.35771528$
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 = 188100.00 is the confined core 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 = 137025.00 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 = 95733.333 is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00406911$

 $psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00406911$
Lstir (Length of stirrups along Y) = 1760.00
Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

 $psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00526591$
Lstir (Length of stirrups along X) = 1360.00
Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

s = 100.00
 $fywe = 656.25$
fce = 24.00
From ((5.A5), TBDY), TBDY: $cc = 0.0050771$
c = confinement factor = 1.30771
 $y1 = 0.0025$
 $sh1 = 0.008$
 $ft1 = 787.50$
 $fy1 = 656.25$
 $su1 = 0.032$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou,min = lb/d = 1.00$
 $su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu1_nominal = 0.08$,
For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs1 = fs = 656.25$
with $Es1 = Es = 200000.00$
 $y2 = 0.0025$

$sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 1.00$
 $su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2_nominal} = 0.08$,
 For calculation of $esu_{2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 656.25$
 with $Es_2 = Es = 200000.00$
 $yv = 0.0025$
 $shv = 0.008$
 $ftv = 787.50$
 $fyv = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 656.25$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.48796927$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.17892207$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.44459423$
 and confined core properties:
 $b = 190.00$
 $d = 477.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.68244627$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.2502303$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.62178438$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y_2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is not satisfied
 --->
 Case/Assumption Rejected.
 --->
 New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)
 --->
 $v < s_{y_1}$ - LHS eq.(4.7) is not satisfied
 --->
 $v < v_{c,y_1}$ - RHS eq.(4.6) is satisfied
 --->
 $cu (4.10) = 0.43574957$
 $MRC (4.17) = 8.0482E+008$
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: $bo, do, d'o$

- N, 1, 2, v normalised to $b_0 \cdot d_0$, instead of $b \cdot d$
- parameters of confined concrete, f_{cc} , c_c , used in lieu of f_c , e_{cu}

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

* c_u (4.10) = 0.5092345

M R_o (4.17) = 9.6827E+008

---->

u = c_u (4.2) = 2.0901588E-005

Mu = M R_o

 Calculation of ratio l_b/l_d

 Adequate Lap Length: $l_b/l_d \geq 1$

 Calculation of Mu2-

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

u = 7.5354574E-005

Mu = 8.4161E+008

 with full section properties:

b = 750.00

d = 507.00

d' = 43.00

v = 0.00108123

N = 9867.325

f_c = 24.00

c_o (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} \cdot \text{Max}(c_u, c_c) = 0.01464812$

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

From (5.4b), TBDY: $c_u = 0.01464812$

w_e ((5.4c), TBDY) = $a_s e \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$

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

 $f_x = 0.03787432$

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

$a_f = 0.14946032$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$

$b_{\max} = 750.00$

$h_{\max} = 550.00$

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

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 748.2496$

 $f_y = 0.03787432$

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

$a_f = 0.14946032$

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

$b_{\max} = 750.00$

hmax = 550.00
From EC8 A.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 748.2496$

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

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$
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.
 $A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{\text{conf,min}} = 137025.00$ 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.
 $A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$
 L_{stir} (Length of stirrups along Y) = 1760.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 262500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$
 L_{stir} (Length of stirrups along X) = 1360.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 262500.00

s = 100.00
 $f_{ywe} = 656.25$
 $f_{ce} = 24.00$
From ((5.A5), TBDY), TBDY: $cc = 0.0050771$
c = confinement factor = 1.30771

$y1 = 0.0025$
 $sh1 = 0.008$
 $ft1 = 787.50$
 $fy1 = 656.25$
 $su1 = 0.032$

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

$l_o/l_{o,min} = l_b/l_d = 1.00$

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

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

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

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

with $fs1 = fs = 656.25$

with $Es1 = Es = 200000.00$

$y2 = 0.0025$
 $sh2 = 0.008$
 $ft2 = 787.50$
 $fy2 = 656.25$
 $su2 = 0.032$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

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

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

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

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

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

with $f_{s2} = f_s = 656.25$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$f_{y_v} = 656.25$

$s_{u_v} = 0.032$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/d = 1.00$

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

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

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

For calculation of $e_{s_{u_v,nominal}}$ and y_v, sh_v, ft_v, f_{y_v} , it is considered

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

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

with $f_{s_v} = f_s = 656.25$

with $E_{s_v} = E_s = 200000.00$

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.05964069$

2 = $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16265642$

v = $A_{s1,mid}/(b \cdot d) \cdot (f_{s_v}/f_c) = 0.14819808$

and confined core properties:

$b = 690.00$

$d = 477.00$

$d' = 13.00$

$f_{cc} (5A.2, \text{TBDY}) = 31.38503$

$cc (5A.5, \text{TBDY}) = 0.0050771$

c = confinement factor = 1.30771

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.068904$

2 = $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.18791999$

v = $A_{s1,mid}/(b \cdot d) \cdot (f_{s_v}/f_c) = 0.17121599$

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

--->

$s_u (4.8) = 0.16240824$

$\mu_u = M_{Rc} (4.15) = 8.4161E+008$

u = $s_u (4.1) = 7.5354574E-005$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 426086.999$

Calculation of Shear Strength at edge 1, $V_{r1} = 426086.999$

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

$V_{Co10} = 426086.999$

$k_{nl} = 1$ (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)

$f_c' = 24.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 867.1065$

$V_u = 0.00020794$
 $d = 0.8 \cdot h = 440.00$
 $N_u = 9867.325$
 $A_g = 137500.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 527787.566$
 where:
 $V_{s1} = 362853.951$ is calculated for section web, with:
 $d = 440.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.22727273$
 $V_{s2} = 164933.614$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 V_f ((11-3)-(11.4), ACI 440) = 267149.446
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = 45^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 507.00
 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: $V_s + V_f \leq 357985.191$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 426086.999$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 426086.999$
 $k_{nl} = 1$ (zero step-static loading)

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

$f_c = 1$ (normal-weight concrete)
 $f_c' = 24.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 867.1065$
 $V_u = 0.00020794$
 $d = 0.8 \cdot h = 440.00$
 $N_u = 9867.325$
 $A_g = 137500.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 527787.566$
 where:
 $V_{s1} = 362853.951$ is calculated for section web, with:
 $d = 440.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.22727273$
 $V_{s2} = 164933.614$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$

$f_y = 525.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 $V_f((11-3)-(11.4), ACI 440) = 267149.446$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 507.00
 $f_{fe}((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 357985.191$
 $bw = 250.00$

 End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rctcs

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 23025.204$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 656.25$
 #####
 Max Height, $H_{max} = 550.00$
 Min Height, $H_{min} = 250.00$
 Max Width, $W_{max} = 750.00$
 Min Width, $W_{min} = 250.00$
 Eccentricity, $Ecc = 250.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.30771
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o / l_{ou, min} > 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$

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

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 5.0286180E-008$
EDGE -B-
Shear Force, $V_b = -5.0286180E-008$
BOTH EDGES
Axial Force, $F = -9867.325$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1231.504$
-Compression: $As_{l,com} = 1231.504$
-Middle: $As_{l,mid} = 2689.203$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.21891$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 820555.407$
with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.2308E+009$
 $\mu_{u1+} = 1.2308E+009$, 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
 $\mu_{u1-} = 1.2308E+009$, 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
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.2308E+009$
 $\mu_{u2+} = 1.2308E+009$, 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
 $\mu_{u2-} = 1.2308E+009$, 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:
 $\mu_u = 7.4763506E-005$
 $\mu_u = 1.2308E+009$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.01464812$$

$$\mu_u \text{ ((5.4c), TBDY)} = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

$$f_x = 0.03787432$$

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

$$af = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$fy = 0.03787432$$

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

$$af = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).
 $psh_{\text{min}} = \text{Min}(psh_x, psh_y) = 0.00406911$

$$psh_x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1760.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1360.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$fy_{we} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

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

$$lo/lou_{\text{min}} = lb/ld = 1.00$$

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

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

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

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

with $f_{s1} = f_s = 656.25$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 656.25$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.19051738$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.19051738$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.41602774$
 and confined core properties:
 $b = 190.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$
 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
 --->
 $su (4.8) = 0.39460211$
 $Mu = MR_c (4.15) = 1.2308E+009$
 $u = su (4.1) = 7.4763506E-005$

 Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu_1 -

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

$$u = 7.4763506E-005$$

$$\mu = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } \phi_u: \phi_u = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01464812$$

$$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07767542$$

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

$$\phi_{fx} = 0.03787432$$

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

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 39233.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 748.2496$$

$$\phi_{fy} = 0.03787432$$

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

$$\alpha_f = 0.14946032$$

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

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 748.2496$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$\text{psh}_{, \text{min}} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00406911$$

$$\text{psh}_x ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} (\text{Length of stirrups along Y}) = 1760.00$$

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

$$A_{\text{sec}} (\text{section area}) = 262500.00$$

$$\text{psh}_y ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} (\text{Length of stirrups along X}) = 1360.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

s = 100.00
fywe = 656.25
fce = 24.00

From ((5.A.5), TBDY), TBDY: cc = 0.0050771
c = confinement factor = 1.30771

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19051738

2 = Asl,com/(b*d)*(fs2/fc) = 0.19051738

v = Asl,mid/(b*d)*(fsv/fc) = 0.41602774

and confined core properties:

b = 190.00
d = 677.00
d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$$

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

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

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

--->
 μ (4.8) = 0.39460211

$$\mu = M_{Rc} \text{ (4.15)} = 1.2308E+009$$

$$u = \mu \text{ (4.1)} = 7.4763506E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{2+}

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

$$u = 7.4763506E-005$$

$$\mu = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01464812$$

$$\mu \text{ (5.4c), TBDY} = a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

 $f_x = 0.03787432$

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

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

 $f_y = 0.03787432$

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

$$a_f = 0.14946032$$

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

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

 $R = 40.00$

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

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

$$E_f = 64828.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $psh_{\text{min}} = \text{Min}(psh_x, psh_y) = 0.00406911$

$$psh_x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

$$psh_y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 24.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

c = confinement factor = 1.30771

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

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

$$l_o/l_{o,\text{min}} = l_b/l_d = 1.00$$

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

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

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

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

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$su_2 = 0.032$$

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

$$l_o/l_{o,\text{min}} = l_b/l_{b,\text{min}} = 1.00$$

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

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

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

y_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 $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$su_v = 0.032$$

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

$l_0/l_{0,min} = l_b/l_d = 1.00$

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

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

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

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

γ_1 , sh_1, f_{t1}, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19051738$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.19051738$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.41602774$

and confined core properties:

$b = 190.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 31.38503$

$cc (5A.5, TBDY) = 0.0050771$

$c =$ confinement factor $= 1.30771$

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.26178921$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.26178921$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.57166216$

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

$s_u (4.8) = 0.39460211$

$M_u = M_{Rc} (4.15) = 1.2308E+009$

$u = s_u (4.1) = 7.4763506E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2} -

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

$u = 7.4763506E-005$

$M_u = 1.2308E+009$

with full section properties:

$b = 250.00$

$d = 707.00$

$d' = 43.00$

$v = 0.0023261$

$N = 9867.325$

$f_c = 24.00$

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

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, cc) = 0.01464812$

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

From (5.4b), TBDY: $c_u = 0.01464812$

$w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$

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

$f_x = 0.03787432$

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

$$af = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$fy = 0.03787432$$

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

$$af = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$$psh_{\text{min}} = \text{Min}(psh_x, psh_y) = 0.00406911$$

$$psh_x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1760.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1360.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$fy_{we} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

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

$$lo/lou_{\text{min}} = lb/ld = 1.00$$

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

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

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

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

$$\text{with } fs1 = fs = 656.25$$

with $E_s1 = E_s = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 1.00$
 $su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2_nominal} = 0.08$,
 For calculation of $esu_{2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 656.25$
 with $E_s2 = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.19051738$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.19051738$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.41602774$
 and confined core properties:
 $b = 190.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.26178921$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.26178921$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.57166216$
 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
 ---->
 $su (4.8) = 0.39460211$
 $Mu = MRc (4.15) = 1.2308E+009$
 $u = su (4.1) = 7.4763506E-005$

 Calculation of ratio lb/ld

 Adequate Lap Length: $lb/ld \geq 1$

 Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 673185.175$

Calculation of Shear Strength at edge 1, $Vr1 = 673185.175$

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

$VColO = 673185.175$

$knl = 1$ (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)

$fc' = 24.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 0.48500011$

$Vu = 5.0286180E-008$

$d = 0.8 * h = 600.00$

$Nu = 9867.325$

$Ag = 187500.00$

From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 659734.457$

where:

$Vs1 = 164933.614$ is calculated for section web, with:

$d = 200.00$

$Av = 157079.633$

$fy = 525.00$

$s = 100.00$

$Vs1$ is multiplied by $Col1 = 1.00$

$s/d = 0.50$

$Vs2 = 494800.843$ is calculated for section flange, with:

$d = 600.00$

$Av = 157079.633$

$fy = 525.00$

$s = 100.00$

$Vs2$ is multiplied by $Col2 = 1.00$

$s/d = 0.16666667$

Vf ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$dfv = d$ (figure 11.2, ACI 440) = 707.00

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: $Vs + Vf \leq 488161.625$

$bw = 250.00$

Calculation of Shear Strength at edge 2, $Vr2 = 673185.175$

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

$VColO = 673185.175$

$knl = 1$ (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)

$fc' = 24.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 0.48484922$

$Vu = 5.0286180E-008$

$d = 0.8 * h = 600.00$

$Nu = 9867.325$

Ag = 187500.00
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 659734.457$

where:

$V_{s1} = 164933.614$ is calculated for section web, with:

d = 200.00

Av = 157079.633

fy = 525.00

s = 100.00

V_{s1} is multiplied by Col1 = 1.00

s/d = 0.50

$V_{s2} = 494800.843$ is calculated for section flange, with:

d = 600.00

Av = 157079.633

fy = 525.00

s = 100.00

V_{s2} is multiplied by Col2 = 1.00

s/d = 0.16666667

Vf ((11-3)-(11.4), ACI 440) = 372533.843

f = 0.95, for fully-wrapped sections

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

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

This later relation, considered as a function $V_f(\alpha)$, 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

dfv = d (figure 11.2, ACI 440) = 707.00

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

Ef = 64828.00

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

with fu = 0.01

From (11-11), ACI 440: $V_s + V_f \leq 488161.625$

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\phi = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $E_{cc} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_b/l_d >= 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -143917.896$
Shear Force, $V_2 = -3183.231$
Shear Force, $V_3 = 74.47086$
Axial Force, $F = -10230.902$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 2261.947$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 2060.885$
Mean Diameter of Tension Reinforcement, $D_bL = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.01174561$
 $u = y + p = 0.01174561$

- Calculation of y -

 $y = (M_y * L_s / 3) / E_{eff} = 0.0105534$ ((4.29), Biskinis Phd))
 $M_y = 6.3263E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1932.54
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 3.8616E+013$
factor = 0.30
Ag = 262500.00
fc' = 24.00
N = 10230.902
 $E_c * I_g = 1.2872E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 8.9410173E-006$
with $f_y = 525.00$
 $d = 507.00$
 $y = 0.42092554$
 $A = 0.04080236$
 $B = 0.02737367$
with $pt = 0.01784573$
 $pc = 0.00654344$
 $pv = 0.01625945$
 $N = 10230.902$

$b = 250.00$
 $\mu = 0.08481262$
 $y_{comp} = 8.8492878E-006$
 with f_c^* (12.3, (ACI 440)) = 24.15812
 $f_c = 24.00$
 $f_l = 0.56655003$
 $b = b_{max} = 750.00$
 $h = h_{max} = 550.00$
 $A_g = 262500.00$
 $g = p_t + p_c + p_v = 0.04064862$
 $r_c = 40.00$
 $A_e/A_c = 0.16554652$
 Effective FRP thickness, $t_f = N_L * t * \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 23025.204$
 $y = 0.42093589$
 $A = 0.04043492$
 $B = 0.02721993$
 with $E_s = 200000.00$

 Calculation of ratio l_b/d

 Adequate Lap Length: $l_b/d \geq 1$

 - Calculation of ρ -

 From table 10-8: $\rho = 0.00119221$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/d < 1$

shear control ratio $V_y E / V_{col} O E = 1.51499$

$d = 507.00$

$s = 0.00$

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

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

$L_{stir} = 1360.00$, is the total Length of all stirrups parallel to loading (shear) direction

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

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

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

$N_{UD} = 10230.902$

$A_g = 262500.00$

$f_{cE} = 24.00$

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

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.04064862$

$b = 250.00$

$d = 507.00$

$f_{cE} = 24.00$

 End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 3

column C1, Floor 1

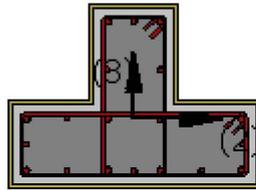
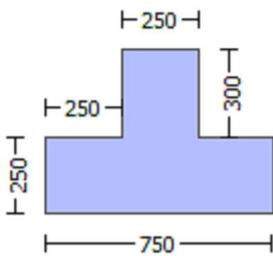
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 23025.204$

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, $f_c = f_{cm} = 24.00$

Existing material: Steel Strength, $f_s = f_{sm} = 525.00$

#####

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $Ecc = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{o,u,min} = l_b/d \geq 1$)
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, $M_a = -143917.896$
Shear Force, $V_a = 74.47086$
EDGE -B-
Bending Moment, $M_b = -79021.292$
Shear Force, $V_b = -74.47086$
BOTH EDGES
Axial Force, $F = -10230.902$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 2261.947$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 2060.885$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 348112.466$
 $V_n ((10.3), ASCE 41-17) = k_n \phi V_{CoI} = 348112.466$
 $V_{CoI} = 348112.466$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.0012402$

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

= 1 (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 143917.896$
 $V_u = 74.47086$
 $d = 0.8 \cdot h = 440.00$
 $N_u = 10230.902$
 $A_g = 137500.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 422230.053$
where:
 $V_{s1} = 290283.161$ is calculated for section web, with:
 $d = 440.00$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.22727273$
 $V_{s2} = 131946.891$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$

$f_y = 420.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 $V_f((11-3)-(11.4), ACI 440) = 267149.446$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 $\ln(11.3) \sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 507.00
 $f_{fe}((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 292293.685$
 $b_w = 250.00$

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 $\theta = 1.3088350E-005$
 $y = (M_y * L_s / 3) / E_{eff} = 0.0105534$ ((4.29), Biskinis Phd))
 $M_y = 6.3263E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1932.54
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 3.8616E+013$
 $\text{factor} = 0.30$
 $A_g = 262500.00$
 $f_c' = 24.00$
 $N = 10230.902$
 $E_c * I_g = 1.2872E+014$

Calculation of Yielding Moment M_y

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

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 8.9410173E-006$
 with $f_y = 525.00$
 $d = 507.00$
 $y = 0.42092554$
 $A = 0.04080236$
 $B = 0.02737367$
 with $p_t = 0.01784573$
 $p_c = 0.00654344$
 $p_v = 0.01625945$
 $N = 10230.902$
 $b = 250.00$
 $\theta = 0.08481262$
 $y_{comp} = 8.8492878E-006$
 with $f_c' (12.3, (ACI 440)) = 24.15812$
 $f_c = 24.00$
 $f_l = 0.56655003$
 $b = b_{max} = 750.00$
 $h = h_{max} = 550.00$
 $A_g = 262500.00$
 $g = p_t + p_c + p_v = 0.04064862$

$r_c = 40.00$
 $A_e/A_c = 0.16554652$
Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 23025.204$
 $y = 0.42093589$
 $A = 0.04043492$
 $B = 0.02721993$
with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

End Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 4

column C1, Floor 1

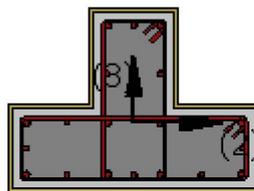
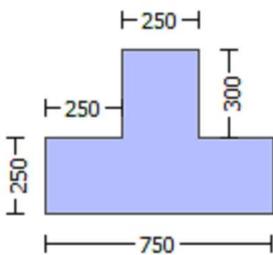
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rctcs

Constant Properties

```

Knowledge Factor,  $\phi = 1.00$ 
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$ 
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$ 
Concrete Elasticity,  $E_c = 23025.204$ 
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,  $f_s = 1.25 \cdot f_{sm} = 656.25$ 
#####
Max Height,  $H_{max} = 550.00$ 
Min Height,  $H_{min} = 250.00$ 
Max Width,  $W_{max} = 750.00$ 
Min Width,  $W_{min} = 250.00$ 
Eccentricity,  $Ecc = 250.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.30771
Element Length,  $L = 3000.00$ 
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou, min} >= 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $NoDir = 1$ 
Fiber orientations,  $bi = 0.00^\circ$ 
Number of layers,  $NL = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
At local axis: 3
EDGE -A-
Shear Force,  $V_a = 0.00020794$ 
EDGE -B-
Shear Force,  $V_b = -0.00020794$ 
BOTH EDGES
Axial Force,  $F = -9867.325$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $A_{st} = 0.00$ 
-Compression:  $A_{sc} = 5152.212$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $A_{st, ten} = 2261.947$ 
-Compression:  $A_{sl, com} = 829.3805$ 
-Middle:  $A_{sl, mid} = 2060.885$ 
-----
-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 1.51499$ 
Member Controlled by Shear ( $V_e/V_r > 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 645516.591$ 
with
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 9.6827E+008$ 
 $M_{u1+} = 9.6827E+008$ , 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
 $M_{u1-} = 8.4161E+008$ , 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 9.6827E+008$$

$M_{u2+} = 9.6827E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 8.4161E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

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

$$\phi_u = 2.0901588E-005$$

$$M_u = 9.6827E+008$$

with full section properties:

$$b = 250.00$$

$$d = 507.00$$

$$d' = 43.00$$

$$v = 0.0032437$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464812$$

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

$$\text{From (5.4b), TB DY: } \phi_u = 0.01464812$$

$$\omega_e \text{ ((5.4c), TB DY) } = a_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07767542$$

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

$$\phi_x = 0.03787432$$

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

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 39233.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$\phi_y = 0.03787432$$

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

$$a_f = 0.14946032$$

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

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00406911$$

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00406911$$

$$Lstir (\text{Length of stirrups along } Y) = 1760.00$$

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

$$Asec (\text{section area}) = 262500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00526591$$

$$Lstir (\text{Length of stirrups along } X) = 1360.00$$

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

$$Asec (\text{section area}) = 262500.00$$

$$s = 100.00$$

$$fywe = 656.25$$

$$fce = 24.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

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

$$lo/lou,min = lb/d = 1.00$$

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

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

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

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

$$\text{with } fs1 = fs = 656.25$$

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

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 787.50$$

$$fy2 = 656.25$$

$$su2 = 0.032$$

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

$$lo/lou,min = lb/lb,min = 1.00$$

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

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

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

$$y2, sh2,ft2,fy2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE41-17.}$$

$$\text{with } fs2 = fs = 656.25$$

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

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 787.50$$

$$fyv = 656.25$$

$$suv = 0.032$$

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

$$lo/lou,min = lb/d = 1.00$$

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

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

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

$$yv, shv,ftv,fyv, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE41-17.}$$

$$\text{with } fsv = fs = 656.25$$

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.48796927$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.17892207$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.44459423$$

and confined core properties:

$$b = 190.00$$

$$d = 477.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 31.38503$$

$$c_c (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.68244627$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.2502303$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.62178438$$

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 not satisfied

---->

Case/Assumption Rejected.

---->

New Case/Assumption: Unconfined full section - Spalling of concrete cover

' satisfies Eq. (4.4)

---->

$v < v_{s,y1}$ - LHS eq.(4.7) is not satisfied

---->

$v < v_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

$$c_u (4.10) = 0.43574957$$

$$M_{Rc} (4.17) = 8.0482E+008$$

---->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o

- $N, 1, 2, v$ normalised to b_o*d_o , instead of $b*d$

- f_{cc}, c_c parameters of confined concrete, f_{cc}, c_c , used in lieu of f_c, c_c

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

$$^*c_u (4.10) = 0.5092345$$

$$M_{Ro} (4.17) = 9.6827E+008$$

---->

$$u = c_u (4.2) = 2.0901588E-005$$

$$M_u = M_{Ro}$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u1} -

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

$$u = 7.5354574E-005$$

$$Mu = 8.4161E+008$$

with full section properties:

$$b = 750.00$$

$$d = 507.00$$

$$d' = 43.00$$

$$v = 0.00108123$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01464812$$

$$\omega_e \text{ ((5.4c), TBDY) } = \alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07767542$$

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

$$\phi_x = 0.03787432$$

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

$$\alpha f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$\phi_y = 0.03787432$$

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

$$\alpha f = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$$

$$p_{sh,x} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 1760.00$$

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

$$A_{\text{sec}} \text{ (section area) } = 262500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 1360.00$$

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

$$A_{\text{sec}} \text{ (section area) } = 262500.00$$

$$s = 100.00$$

$$fywe = 656.25$$

$$fce = 24.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

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

$$lo/lou,min = lb/d = 1.00$$

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

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

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

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

$$\text{with } fs1 = fs = 656.25$$

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

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 787.50$$

$$fy2 = 656.25$$

$$su2 = 0.032$$

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

$$lo/lou,min = lb/lb,min = 1.00$$

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

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

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

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

$$\text{with } fs2 = fs = 656.25$$

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

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 787.50$$

$$fyv = 656.25$$

$$suv = 0.032$$

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

$$lo/lou,min = lb/d = 1.00$$

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

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

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

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

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

$$\text{with } fsv = fs = 656.25$$

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.05964069$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.16265642$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.14819808$$

and confined core properties:

$$b = 690.00$$

$$d = 477.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 31.38503$$

$$cc (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.068904$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.18791999$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.17121599$$

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

--->

$$s_u(4.8) = 0.16240824$$

$$M_u = M_{Rc}(4.15) = 8.4161E+008$$

$$u = s_u(4.1) = 7.5354574E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2+}

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

$$u = 2.0901588E-005$$

$$M_u = 9.6827E+008$$

with full section properties:

$$b = 250.00$$

$$d = 507.00$$

$$d' = 43.00$$

$$v = 0.0032437$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } \kappa_u: \kappa_u^* = \text{shear_factor} * \text{Max}(\kappa_u, \kappa_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } \kappa_u = 0.01464812$$

$$\omega_e(5.4c, TBDY) = \alpha * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

$$f_x = 0.03787432$$

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

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

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

$$\alpha_f = 0.14946032$$

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

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.35771528$$

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.

$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

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

$lo/lo_{u,min} = lb/l_d = 1.00$

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

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

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

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

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

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

$lo/lo_{u,min} = lb/l_{b,min} = 1.00$

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

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

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

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

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$su_v = 0.032$

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

Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 γ_v , shv,ftv,fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 γ_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 $fsv = fs = 656.25$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.48796927$
 $2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.17892207$
 $v = Asl_{mid}/(b*d)*(fsv/fc) = 0.44459423$

and confined core properties:

$b = 190.00$
 $d = 477.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.68244627$
 $2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.2502303$
 $v = Asl_{mid}/(b*d)*(fsv/fc) = 0.62178438$

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 not satisfied
 --->

Case/Assumption Rejected.

--->
 New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)

--->
 $v < s_{y1}$ - LHS eq.(4.7) is not satisfied
 --->
 $v < v_{c,y1}$ - RHS eq.(4.6) is satisfied
 --->

$cu (4.10) = 0.43574957$
 $MRc (4.17) = 8.0482E+008$

--->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: $bo, do, d'o$
 - $N, 1, 2, v$ normalised to $bo*do$, instead of $b*d$
 - - parameters of confined concrete, f_{cc}, cc , used in lieu of fc, ec

Subcase: Rupture of tension steel

--->
 $v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied
 --->

Subcase rejected

--->
 New Subcase: Failure of compression zone

--->
 $v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied
 --->
 $v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied
 --->

$*cu (4.10) = 0.5092345$
 $MRo (4.17) = 9.6827E+008$

--->
 $u = cu (4.2) = 2.0901588E-005$
 $Mu = MRo$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_2

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

$\mu = 7.5354574E-005$

$\mu_2 = 8.4161E+008$

with full section properties:

$b = 750.00$

$d = 507.00$

$d' = 43.00$

$v = 0.00108123$

$N = 9867.325$

$f_c = 24.00$

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

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01464812$

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

From (5.4b), TBDY: $\mu_c = 0.01464812$

μ_{we} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$

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

$f_x = 0.03787432$

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

$\alpha_f = 0.14946032$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$

$b_{\max} = 750.00$

$h_{\max} = 550.00$

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

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 748.2496$

$f_y = 0.03787432$

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

$\alpha_f = 0.14946032$

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

$b_{\max} = 750.00$

$h_{\max} = 550.00$

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

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 748.2496$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00406911$$

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00406911$$

$$Lstir (\text{Length of stirrups along Y}) = 1760.00$$

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

$$Asec (\text{section area}) = 262500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00526591$$

$$Lstir (\text{Length of stirrups along X}) = 1360.00$$

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

$$Asec (\text{section area}) = 262500.00$$

$$s = 100.00$$

$$fywe = 656.25$$

$$fce = 24.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

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

$$lo/lou,min = lb/d = 1.00$$

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

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

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

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

$$\text{with } fs1 = fs = 656.25$$

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

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 787.50$$

$$fy2 = 656.25$$

$$su2 = 0.032$$

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

$$lo/lou,min = lb/lb,min = 1.00$$

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

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

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

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

$$\text{with } fs2 = fs = 656.25$$

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

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 787.50$$

$$fyv = 656.25$$

$$suv = 0.032$$

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

$$lo/lou,min = lb/d = 1.00$$

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

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

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

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

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

$$\text{with } fsv = fs = 656.25$$

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.05964069$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.16265642$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.14819808$$

and confined core properties:

$$b = 690.00$$

$$d = 477.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 31.38503$$

$$c_c (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.068904$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.18791999$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.17121599$$

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

--->

$$s_u (4.8) = 0.16240824$$

$$M_u = M_{Rc} (4.15) = 8.4161E+008$$

$$u = s_u (4.1) = 7.5354574E-005$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 426086.999$

Calculation of Shear Strength at edge 1, $V_{r1} = 426086.999$

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

$$V_{Co10} = 426086.999$$

$k_{nl} = 1$ (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)

$$f_c' = 24.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 867.1065$$

$$V_u = 0.00020794$$

$$d = 0.8 * h = 440.00$$

$$N_u = 9867.325$$

$$A_g = 137500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 527787.566$$

where:

$V_{s1} = 362853.951$ is calculated for section web, with:

$$d = 440.00$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

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

$$s/d = 0.22727273$$

$V_{s2} = 164933.614$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

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

$$s/d = 0.50$$

$$V_f ((11-3)-(11.4), ACI 440) = 267149.446$$

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

total thickness per orientation, $tf_1 = NL \cdot t / \text{NoDir} = 1.016$

$df_v = d$ (figure 11.2, ACI 440) = 507.00

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: $V_s + V_f \leq 357985.191$

$bw = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 426086.999$

$V_{r2} = V_{CoI}$ ((10.3), ASCE 41-17) = $kn_1 \cdot V_{CoI0}$

$V_{CoI0} = 426086.999$

$kn_1 = 1$ (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).

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

$f_c' = 24.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 867.1065$

$V_u = 0.00020794$

$d = 0.8 \cdot h = 440.00$

$N_u = 9867.325$

$A_g = 137500.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 527787.566$

where:

$V_{s1} = 362853.951$ is calculated for section web, with:

$d = 440.00$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

V_{s1} is multiplied by $Col_1 = 1.00$

$s/d = 0.22727273$

$V_{s2} = 164933.614$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

V_{s2} is multiplied by $Col_2 = 1.00$

$s/d = 0.50$

V_f ((11-3)-(11.4), ACI 440) = 267149.446

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

total thickness per orientation, $tf_1 = NL \cdot t / \text{NoDir} = 1.016$

$df_v = d$ (figure 11.2, ACI 440) = 507.00

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: $V_s + V_f \leq 357985.191$

$bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
Concrete Elasticity, $E_c = 23025.204$
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, $f_s = 1.25 \cdot f_{sm} = 656.25$

Max Height, $H_{max} = 550.00$
Min Height, $H_{min} = 250.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 250.00$
Eccentricity, $Ecc = 250.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.30771
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} > 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 5.0286180E-008$
EDGE -B-
Shear Force, $V_b = -5.0286180E-008$
BOTH EDGES
Axial Force, $F = -9867.325$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 1231.504$

-Compression: $Asl,com = 1231.504$
-Middle: $Asl,mid = 2689.203$

Calculation of Shear Capacity ratio , $Ve/Vr = 1.21891$

Member Controlled by Shear ($Ve/Vr > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $Ve = (Mpr1 + Mpr2)/ln = 820555.407$

with
 $Mpr1 = \text{Max}(Mu1+ , Mu1-) = 1.2308E+009$
 $Mu1+ = 1.2308E+009$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $Mu1- = 1.2308E+009$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $Mpr2 = \text{Max}(Mu2+ , Mu2-) = 1.2308E+009$
 $Mu2+ = 1.2308E+009$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $Mu2- = 1.2308E+009$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of $Mu1+$

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

$\epsilon_u = 7.4763506E-005$

$Mu = 1.2308E+009$

with full section properties:

$b = 250.00$

$d = 707.00$

$d' = 43.00$

$v = 0.0023261$

$N = 9867.325$

$f_c = 24.00$

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

Final value of ϵ_{cu} : $\epsilon_{cu}^* = \text{shear_factor} * \text{Max}(\epsilon_{cu}, \epsilon_{cc}) = 0.01464812$

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

From (5.4b), TBDY: $\epsilon_{cu} = 0.01464812$

$\epsilon_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\epsilon_{fx}, \epsilon_{fy}) = 0.07767542$

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

$\epsilon_{fx} = 0.03787432$

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

$\alpha_f = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$

$b_{max} = 750.00$

$h_{max} = 550.00$

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

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 748.2496$

$\epsilon_{fy} = 0.03787432$

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

$\alpha_f = 0.14946032$

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

$b_{max} = 750.00$

$h_{max} = 550.00$

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

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 748.2496$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.35771528$$

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.

$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00406911$

$$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1760.00$$

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

$$A_{sec} \text{ (section area)} = 262500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1360.00$$

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

$$A_{sec} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

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

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

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

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.

$$\text{with } fs_1 = fs = 656.25$$

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

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$su_2 = 0.032$$

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

$$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$$

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

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.

$$\text{with } fs_2 = fs = 656.25$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19051738

2 = Asl,com/(b*d)*(fs2/fc) = 0.19051738

v = Asl,mid/(b*d)*(fsv/fc) = 0.41602774

and confined core properties:

b = 190.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

1 = Asl,ten/(b*d)*(fs1/fc) = 0.26178921

2 = Asl,com/(b*d)*(fs2/fc) = 0.26178921

v = Asl,mid/(b*d)*(fsv/fc) = 0.57166216

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) = 0.39460211

Mu = MRc (4.15) = 1.2308E+009

u = su (4.1) = 7.4763506E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

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

u = 7.4763506E-005

Mu = 1.2308E+009

with full section properties:

b = 250.00

d = 707.00

d' = 43.00

v = 0.0023261

N = 9867.325

fc = 24.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01464812

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

From (5.4b), TBDY: cu = 0.01464812

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.07767542

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

fx = 0.03787432

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

$$af = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$fy = 0.03787432$$

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

$$af = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).
 $psh_{\text{min}} = \text{Min}(psh_x, psh_y) = 0.00406911$

$$psh_x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1760.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1360.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$fy_{we} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

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

$$lo/lou_{\text{min}} = lb/d = 1.00$$

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

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

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

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

with $f_{s1} = f_s = 656.25$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 656.25$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.19051738$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.19051738$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.41602774$
 and confined core properties:
 $b = 190.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$
 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
 --->
 $su (4.8) = 0.39460211$
 $Mu = MR_c (4.15) = 1.2308E+009$
 $u = su (4.1) = 7.4763506E-005$

 Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu_{2+}

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

$$\mu = 7.4763506E-005$$

$$\mu = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } \mu: \mu = \text{shear_factor} * \text{Max}(\mu_c, \mu_s) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } \mu_c = 0.01464812$$

$$\mu_s ((5.4c), \text{TBDY}) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

$$f_x = 0.03787432$$

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

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

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

$$\alpha_f = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00406911$$

$$\text{psh}_x ((5.4d), \text{TBDY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} (\text{Length of stirrups along } Y) = 1760.00$$

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

$$A_{\text{sec}} (\text{section area}) = 262500.00$$

$$\text{psh}_y ((5.4d), \text{TBDY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} (\text{Length of stirrups along } X) = 1360.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

s = 100.00
fywe = 656.25
fce = 24.00

From ((5.A.5), TBDY), TBDY: cc = 0.0050771
c = confinement factor = 1.30771

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19051738

2 = Asl,com/(b*d)*(fs2/fc) = 0.19051738

v = Asl,mid/(b*d)*(fsv/fc) = 0.41602774

and confined core properties:

b = 190.00
d = 677.00
d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$$

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

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

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

--->
 μ (4.8) = 0.39460211

$$\mu = M_{Rc} \text{ (4.15)} = 1.2308E+009$$

$$u = \mu \text{ (4.1)} = 7.4763506E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_2 -

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

$$u = 7.4763506E-005$$

$$\mu = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01464812$$

$$\mu \text{ (5.4c), TBDY} = a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

 $f_x = 0.03787432$

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

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

 $f_y = 0.03787432$

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

$$a_f = 0.14946032$$

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

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

 $R = 40.00$

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

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

$$E_f = 64828.00$$

u,f = 0.015

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.35771528

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 = 188100.00 is the confined core 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 = 137025.00 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 = 95733.333 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) = 0.00406911

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00406911

Lstir (Length of stirrups along Y) = 1760.00

Astir (stirrups area) = 78.53982

Asec (section area) = 262500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00526591

Lstir (Length of stirrups along X) = 1360.00

Astir (stirrups area) = 78.53982

Asec (section area) = 262500.00

s = 100.00

fywe = 656.25

fce = 24.00

From ((5.A5), TBDY), TBDY: cc = 0.0050771

c = confinement factor = 1.30771

y1 = 0.0025

sh1 = 0.008

ft1 = 787.50

fy1 = 656.25

su1 = 0.032

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

lo/lou,min = lb/l_d = 1.00

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

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

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

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

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 787.50

fy2 = 656.25

su2 = 0.032

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

lo/lou,min = lb/l_b,min = 1.00

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

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

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

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

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025

shv = 0.008

ftv = 787.50

fyv = 656.25

suv = 0.032

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

$l_0/l_{0,min} = l_b/l_d = 1.00$

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

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

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

For calculation of $e_{suv,nominal}$ and γ_v , $sh_v, ft_v, f_{y,v}$, it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, 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 $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.19051738$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.19051738$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.41602774$

and confined core properties:

$b = 190.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 31.38503$

$cc (5A.5, TBDY) = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.26178921$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.26178921$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.57166216$

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

$s_u (4.8) = 0.39460211$

$M_u = MR_c (4.15) = 1.2308E+009$

$u = s_u (4.1) = 7.4763506E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 673185.175$

Calculation of Shear Strength at edge 1, $V_{r1} = 673185.175$

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

$V_{Co10} = 673185.175$

$k_{nl} = 1$ (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)

$f_c' = 24.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 0.48500011$

$V_u = 5.0286180E-008$

$d = 0.8 \cdot h = 600.00$

$N_u = 9867.325$

$A_g = 187500.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 659734.457$

where:

$V_{s1} = 164933.614$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 525.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 494800.843$ is calculated for section flange, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.16666667$
 V_f ((11-3)-(11.4), ACI 440) = 372533.843
 $f = 0.95$, 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, $t_{f1} = NL * t / \text{NoDir} = 1.016$
 $df_v = d$ (figure 11.2, ACI 440) = 707.00
 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: $V_s + V_f \leq 488161.625$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 673185.175$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$
 $V_{Col0} = 673185.175$
 $k_{nl} = 1$ (zero step-static loading)

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

$\beta = 1$ (normal-weight concrete)
 $f_c' = 24.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/d = 2.00$
 $\mu_u = 0.48484922$
 $V_u = 5.0286180E-008$
 $d = 0.8 * h = 600.00$
 $N_u = 9867.325$
 $A_g = 187500.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 659734.457$
 where:
 $V_{s1} = 164933.614$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 494800.843$ is calculated for section flange, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.16666667$
 V_f ((11-3)-(11.4), ACI 440) = 372533.843
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 488161.625$

$b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $E_{cc} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b / l_d > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -9.6610E+006$

Shear Force, $V_2 = -3183.231$

Shear Force, $V_3 = 74.47086$

Axial Force, $F = -10230.902$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{st,ten} = 1231.504$

-Compression: $A_{sc,com} = 1231.504$

-Middle: $A_{st,mid} = 2689.203$

Mean Diameter of Tension Reinforcement, $D_bL = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.01279531$

$u = y + p = 0.01279531$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.01046855$ ((4.29), Biskinis Phd))

$M_y = 6.5616E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3034.966

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 6.3409E+013$

factor = 0.30

$A_g = 262500.00$

$f_c' = 24.00$

$N = 10230.902$

$E_c * I_g = 2.1136E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 5.4983477E-006$

with $f_y = 525.00$

$d = 707.00$

$y = 0.32472963$

$A = 0.02925997$

$B = 0.01557156$

with $p_t = 0.00696749$

$p_c = 0.00696749$

$p_v = 0.01521473$

$N = 10230.902$

$b = 250.00$

" = 0.06082037

$y_{comp} = 8.2387023E-006$

with f_c^* (12.3, (ACI 440)) = 24.16756

$f_c = 24.00$

$f_l = 0.56655003$

$b = b_{max} = 750.00$

$h = h_{max} = 550.00$

$A_g = 262500.00$

$g = p_t + p_c + p_v = 0.02914971$

$r_c = 40.00$

$A_e / A_c = 0.17542991$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 23025.204$

$y = 0.32435731$

$A = 0.02899653$

$B = 0.01546131$

with $E_s = 200000.00$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of ρ -

From table 10-8: $\rho = 0.00232676$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/d < 1$

shear control ratio $V_y E / V_{Co} I_{OE} = 1.21891$

$d = 707.00$

$s = 0.00$

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

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

$L_{stir} = 1760.00$, is the total Length of all stirrups parallel to loading (shear) direction

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

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

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

$N_{UD} = 10230.902$

$A_g = 262500.00$

$f_{cE} = 24.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02914971$

$b = 250.00$

$d = 707.00$

$f_{cE} = 24.00$

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 5

column C1, Floor 1

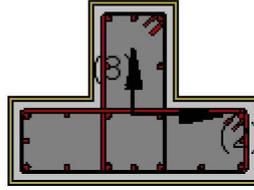
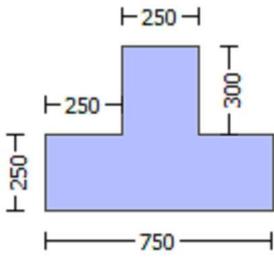
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

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

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 23025.204$

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, $f_c = f_{cm} = 24.00$

Existing material: Steel Strength, $f_s = f_{sm} = 525.00$

#####

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $Ecc = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d >= 1$)

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, $M_a = -9.6610E+006$

Shear Force, $V_a = -3183.231$
EDGE -B-
Bending Moment, $M_b = 108875.895$
Shear Force, $V_b = 3183.231$
BOTH EDGES
Axial Force, $F = -10230.902$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{s,ten} = 1231.504$
-Compression: $A_{s,com} = 1231.504$
-Middle: $A_{s,mid} = 2689.203$
Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 550083.022$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI0} = 550083.022$
 $V_{CoI} = 550083.022$
 $k_n = 1.00$
displacement_ductility_demand = 0.02254149

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

= 1 (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 108875.895$
 $V_u = 3183.231$
 $d = 0.8 \cdot h = 600.00$
 $N_u = 10230.902$
 $A_g = 187500.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 527787.566$
where:
 $V_{s1} = 131946.891$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 395840.674$ is calculated for section flange, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.16666667$
 V_f ((11-3)-(11.4), ACI 440) = 372533.843
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 707.00
 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: $V_s + V_f \leq 398582.298$

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 $\theta = 2.3325811E-005$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00103479$ ((4.29), Biskinis Phd))
 $M_y = 6.5616E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 6.3409E+013$
factor = 0.30
 $A_g = 262500.00$
 $f_c' = 24.00$
 $N = 10230.902$
 $E_c * I_g = 2.1136E+014$

Calculation of Yielding Moment M_y

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

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 5.4983477E-006$
with $f_y = 525.00$
 $d = 707.00$
 $y = 0.32472963$
 $A = 0.02925997$
 $B = 0.01557156$
with $pt = 0.00696749$
 $pc = 0.00696749$
 $pv = 0.01521473$
 $N = 10230.902$
 $b = 250.00$
 $\theta = 0.06082037$
 $y_{comp} = 8.2387023E-006$
with $f_c' (12.3, (ACI 440)) = 24.16756$
 $f_c = 24.00$
 $f_l = 0.56655003$
 $b = b_{max} = 750.00$
 $h = h_{max} = 550.00$
 $A_g = 262500.00$
 $g = pt + pc + pv = 0.02914971$
 $rc = 40.00$
 $A_e / A_c = 0.17542991$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 23025.204$
 $y = 0.32435731$
 $A = 0.02899653$
 $B = 0.01546131$
with $E_s = 200000.00$

Calculation of ratio l_b / d

Adequate Lap Length: $l_b / d \geq 1$

End Of Calculation of Shear Capacity for element: column TC1 of floor 1
At local axis: 2
Integration Section: (b)

Calculation No. 6

column C1, Floor 1

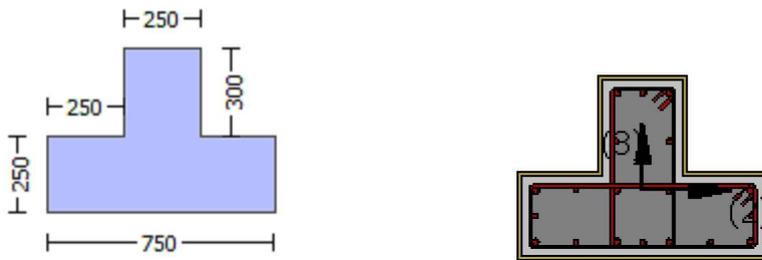
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

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, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $Ecc = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.30771

Element Length, $L = 3000.00$

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

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 0.00020794$
EDGE -B-
Shear Force, $V_b = -0.00020794$
BOTH EDGES
Axial Force, $F = -9867.325$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 2261.947$
-Compression: $A_{st,com} = 829.3805$
-Middle: $A_{st,mid} = 2060.885$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.51499$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 645516.591$
with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 9.6827E+008$

$Mu_{1+} = 9.6827E+008$, 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

$Mu_{1-} = 8.4161E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 9.6827E+008$

$Mu_{2+} = 9.6827E+008$, 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

$Mu_{2-} = 8.4161E+008$, 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:

$\phi_u = 2.0901588E-005$

$M_u = 9.6827E+008$

with full section properties:

$b = 250.00$

$d = 507.00$

$d' = 43.00$

$$v = 0.0032437$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464812$$

$$\text{we (5.4c), TBDY) } = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

$$f_x = 0.03787432$$

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

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

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

$$a_f = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1760.00$$

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

$$A_{sec} \text{ (section area)} = 262500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1360.00$$

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

$$A_{sec} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$f_{y1} = 656.25$$

$$s_{u1} = 0.032$$

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

$$l_o/l_{o,u,min} = l_b/l_d = 1.00$$

$$s_{u1} = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$$

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

For calculation of $e_{s1_nominal}$ and y_1 , sh_1 , ft_1 , f_{y1} , it is considered
characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

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

$$\text{with } f_{s1} = f_s = 656.25$$

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

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$f_{t2} = 787.50$$

$$f_{y2} = 656.25$$

$$s_{u2} = 0.032$$

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

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 1.00$$

$$s_{u2} = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

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

For calculation of $e_{s2_nominal}$ and y_2 , sh_2 , ft_2 , f_{y2} , it is considered
characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_2 , sh_2 , ft_2 , f_{y2} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 656.25$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$f_{t_v} = 787.50$$

$$f_{y_v} = 656.25$$

$$s_{u_v} = 0.032$$

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

$$l_o/l_{o,u,min} = l_b/l_d = 1.00$$

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

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

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

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

$$\text{with } f_{s_v} = f_s = 656.25$$

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

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.48796927$$

$$2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.17892207$$

$$v = A_{s1,mid}/(b*d)*(f_{s_v}/f_c) = 0.44459423$$

and confined core properties:

$$b = 190.00$$

$$d = 477.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 31.38503$$

$$cc (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.68244627$$

$$2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.2502303$$

$$v = A_{s1,mid}/(b*d)*(f_{s_v}/f_c) = 0.62178438$$

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 not satisfied

--->

Case/Assumption Rejected.

--->

New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

--->

$v < s_y1$ - LHS eq.(4.7) is not satisfied

--->

$v < v_c y1$ - RHS eq.(4.6) is satisfied

--->

c_u (4.10) = 0.43574957

M_{Rc} (4.17) = 8.0482E+008

--->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o , d_o , d'_o
- N , 1 , 2 , v normalised to $b_o * d_o$, instead of $b * d$
- - parameters of confined concrete, f_{cc} , c_c , used in lieu of f_c , c_u

--->

Subcase: Rupture of tension steel

--->

$v^* < v^* s_y2$ - LHS eq.(4.5) is not satisfied

--->

$v^* < v^* s_c$ - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^* c_y2$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^* c_y1$ - RHS eq.(4.6) is satisfied

--->

* c_u (4.10) = 0.5092345

M_{Ro} (4.17) = 9.6827E+008

--->

$u = c_u$ (4.2) = 2.0901588E-005

$M_u = M_{Ro}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of M_{u1} -

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

$u = 7.5354574E-005$

$M_u = 8.4161E+008$

with full section properties:

$b = 750.00$

$d = 507.00$

$d' = 43.00$

$v = 0.00108123$

$N = 9867.325$

$f_c = 24.00$

c_o (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$

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

From (5.4b), TBDY: $c_u = 0.01464812$

where $f = a_f * p_f * f_{fe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$

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

 $f_x = 0.03787432$

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

$$af = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$fy = 0.03787432$$

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

$$af = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).
 $psh_{\text{min}} = \text{Min}(psh_x, psh_y) = 0.00406911$

$$psh_x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1760.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1360.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$fy_{we} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

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

$$lo/lou_{\text{min}} = lb/d = 1.00$$

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

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

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

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

with $f_{s1} = f_s = 656.25$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 656.25$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05964069$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.16265642$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.14819808$
 and confined core properties:
 $b = 690.00$
 $d = 477.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.068904$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.18791999$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.17121599$
 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
 --->
 $su (4.8) = 0.16240824$
 $Mu = MR_c (4.15) = 8.4161E+008$
 $u = su (4.1) = 7.5354574E-005$

 Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu_{2+}

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

$$u = 2.0901588E-005$$

$$\mu = 9.6827E+008$$

with full section properties:

$$b = 250.00$$

$$d = 507.00$$

$$d' = 43.00$$

$$v = 0.0032437$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } \phi_u: \phi_u = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01464812$$

$$\phi_{cc} \text{ ((5.4c), TBDY) } = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07767542$$

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

$$\phi_{fx} = 0.03787432$$

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

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 748.2496$$

$$\phi_{fy} = 0.03787432$$

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

$$\alpha_f = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 748.2496$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00406911$$

$$\text{psh}_x \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 1760.00$$

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

$$A_{\text{sec}} \text{ (section area) } = 262500.00$$

$$\text{psh}_y \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 1360.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

s = 100.00
fywe = 656.25
fce = 24.00

From ((5.A.5), TBDY), TBDY: cc = 0.0050771
c = confinement factor = 1.30771

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.48796927

2 = Asl,com/(b*d)*(fs2/fc) = 0.17892207

v = Asl,mid/(b*d)*(fsv/fc) = 0.44459423

and confined core properties:

b = 190.00
d = 477.00
d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.68244627$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.2502303$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.62178438$$

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 not satisfied

---->
Case/Assumption Rejected.

---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

---->
 $v < v_{s,y1}$ - LHS eq.(4.7) is not satisfied

---->
 $v < v_{c,y1}$ - RHS eq.(4.6) is satisfied

---->
 ϵ_{cu} (4.10) = 0.43574957

MRc (4.17) = 8.0482E+008

---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
- N_1, N_2, v normalised to b_o*d_o , instead of $b*d$
- parameters of confined concrete, f_{cc}, ϵ_{cc} , used in lieu of f_c, ϵ_{cu}

---->
Subcase: Rupture of tension steel

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

---->
 $v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->
Subcase rejected

---->
New Subcase: Failure of compression zone

---->
 $v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->
 $v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied

---->
 ϵ^*_{cu} (4.10) = 0.5092345

MRO (4.17) = 9.6827E+008

---->
 $u = \epsilon^*_{cu}$ (4.2) = 2.0901588E-005
 $M_u = M_{RO}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of M_{u2}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 7.5354574E-005$
 $M_u = 8.4161E+008$

with full section properties:
 $b = 750.00$
 $d = 507.00$
 $d' = 43.00$

$$v = 0.00108123$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464812$$

$$\text{we (5.4c), TBDY) } = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

$$f_x = 0.03787432$$

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

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

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

$$a_f = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1760.00$$

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

$$A_{sec} \text{ (section area)} = 262500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1360.00$$

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

$$A_{sec} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$f_{y1} = 656.25$$

$$s_{u1} = 0.032$$

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

$$l_o/l_{o,u,min} = l_b/l_d = 1.00$$

$$s_{u1} = 0.4 * e_{s_{u1,nominal}} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_{u1,nominal}} = 0.08$,

For calculation of $e_{s_{u1,nominal}}$ and y_1, sh_1, ft_1, f_{y1} , it is considered
characteristic value $f_{s_{y1}} = f_{s1}/1.2$, from table 5.1, TBDY.

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

$$\text{with } f_{s1} = f_s = 656.25$$

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

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$f_{t2} = 787.50$$

$$f_{y2} = 656.25$$

$$s_{u2} = 0.032$$

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

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 1.00$$

$$s_{u2} = 0.4 * e_{s_{u2,nominal}} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_{u2,nominal}} = 0.08$,

For calculation of $e_{s_{u2,nominal}}$ and y_2, sh_2, ft_2, f_{y2} , it is considered
characteristic value $f_{s_{y2}} = f_{s2}/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, f_{y2} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 656.25$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$f_{t_v} = 787.50$$

$$f_{y_v} = 656.25$$

$$s_{u_v} = 0.032$$

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

$$l_o/l_{o,u,min} = l_b/l_d = 1.00$$

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

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

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

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

$$\text{with } f_{s_v} = f_s = 656.25$$

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

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.05964069$$

$$2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.16265642$$

$$v = A_{s1,mid}/(b*d)*(f_{s_v}/f_c) = 0.14819808$$

and confined core properties:

$$b = 690.00$$

$$d = 477.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 31.38503$$

$$c_c (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.068904$$

$$2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.18791999$$

$$v = A_{s1,mid}/(b*d)*(f_{s_v}/f_c) = 0.17121599$$

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

--->

$$s_u (4.8) = 0.16240824$$

$$\begin{aligned} \mu &= MRC(4.15) = 8.4161E+008 \\ u &= su(4.1) = 7.5354574E-005 \end{aligned}$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 426086.999$

Calculation of Shear Strength at edge 1, $V_{r1} = 426086.999$

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

$$V_{Col0} = 426086.999$$

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

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 (normal-weight concrete)

$$f_c' = 24.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$\mu = 867.1065$$

$$V_u = 0.00020794$$

$$d = 0.8 * h = 440.00$$

$$N_u = 9867.325$$

$$A_g = 137500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 527787.566$$

where:

$V_{s1} = 362853.951$ is calculated for section web, with:

$$d = 440.00$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

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

$$s/d = 0.22727273$$

$V_{s2} = 164933.614$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

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

$$s/d = 0.50$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 267149.446$$

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

$w_f/s_f = 1$ (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.

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

$$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|), \text{ with:}$$

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 507.00$$

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 357985.191$$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 426086.999$

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

$$V_{Col0} = 426086.999$$

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' = 24.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 867.1065

Vu = 0.00020794

d = 0.8*h = 440.00

Nu = 9867.325

Ag = 137500.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 527787.566

where:

Vs1 = 362853.951 is calculated for section web, with:

d = 440.00

Av = 157079.633

fy = 525.00

s = 100.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.22727273

Vs2 = 164933.614 is calculated for section flange, with:

d = 200.00

Av = 157079.633

fy = 525.00

s = 100.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.50

Vf ((11-3)-(11.4), ACI 440) = 267149.446

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

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

dfv = d (figure 11.2, ACI 440) = 507.00

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 <= 357985.191

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\phi = 1.00$

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

Consequently:

Existing material of Primary Member: Concrete Strength, fc = fcm = 24.00

Existing material of Primary Member: Steel Strength, fs = fsm = 525.00

Concrete Elasticity, Ec = 23025.204

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, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $Ecc = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.30771

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = 5.0286180E-008$

EDGE -B-

Shear Force, $V_b = -5.0286180E-008$

BOTH EDGES

Axial Force, $F = -9867.325$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1231.504$

-Compression: $As_{l,com} = 1231.504$

-Middle: $As_{l,mid} = 2689.203$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.21891$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 820555.407$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.2308E+009$

$Mu_{1+} = 1.2308E+009$, 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

$Mu_{1-} = 1.2308E+009$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.2308E+009$

$Mu_{2+} = 1.2308E+009$, 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

$Mu_{2-} = 1.2308E+009$, 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 Mu1+

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

$$\mu = 7.4763506E-005$$

$$Mu = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464812$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

$$f_x = 0.03787432$$

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

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

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

$$a_f = 0.14946032$$

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

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.35771528$$

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.

$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1760.00$$

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

$$A_{sec} \text{ (section area)} = 262500.00$$

$$psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00526591$$

$$Lstir (\text{Length of stirrups along } X) = 1360.00$$

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

$$Asec (\text{section area}) = 262500.00$$

$$s = 100.00$$

$$fywe = 656.25$$

$$fce = 24.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

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

$$lo/lou,min = lb/ld = 1.00$$

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

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.

$$\text{with } fs1 = fs = 656.25$$

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

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 787.50$$

$$fy2 = 656.25$$

$$su2 = 0.032$$

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

$$lo/lou,min = lb/lb,min = 1.00$$

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

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.

$$\text{with } fs2 = fs = 656.25$$

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

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 787.50$$

$$fyv = 656.25$$

$$suv = 0.032$$

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

$$lo/lou,min = lb/ld = 1.00$$

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

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.

$$\text{with } fsv = fs = 656.25$$

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.19051738$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.19051738$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.41602774$$

and confined core properties:

$$b = 190.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 31.38503$$

$$c_c (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$$

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

---->

$$s_u (4.8) = 0.39460211$$

$$\mu_u = M_{Rc} (4.15) = 1.2308E+009$$

$$u = s_u (4.1) = 7.4763506E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{u1} -

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

$$u = 7.4763506E-005$$

$$\mu_u = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464812$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

$$f_x = 0.03787432$$

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

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

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

$$a_f = 0.14946032$$

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

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

$s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

c = confinement factor = 1.30771

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

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

$l_o/l_{o,min} = l_b/l_d = 1.00$

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

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

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

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

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

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

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

For calculation of $esu2_{\text{nominal}}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

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 $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$$f_{tv} = 787.50$$

$$f_{yv} = 656.25$$

$$s_{uv} = 0.032$$

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

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

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

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

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

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

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

$$\text{with } f_{sv} = f_s = 656.25$$

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.19051738$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.19051738$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.41602774$$

and confined core properties:

$$b = 190.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 31.38503$$

$$c_c (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$$

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

$$s_u (4.8) = 0.39460211$$

$$M_u = M_{Rc} (4.15) = 1.2308E+009$$

$$u = s_u (4.1) = 7.4763506E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2+}

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

$$u = 7.4763506E-005$$

$$M_u = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464812$$

$$w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

$$f_x = 0.03787432$$

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

$$a_f = 0.14946032$$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 748.2496$

$$f_y = 0.03787432$$

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

$$a_f = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 748.2496$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1760.00$$

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

$$A_{sec} \text{ (section area)} = 262500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1360.00$$

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

$$A_{sec} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 24.00$$

From ((5.A5), TBDY), TBDY: $c_c = 0.0050771$

$$c = \text{confinement factor} = 1.30771$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

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

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

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

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 $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

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

with $f_{s1} = f_s = 656.25$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

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

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

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered

characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

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

with $f_{s2} = f_s = 656.25$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$su_v = 0.032$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

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

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.

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

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.19051738$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.19051738$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.41602774$

and confined core properties:

$b = 190.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 31.38503$

$cc (5A.5, TBDY) = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.26178921$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.26178921$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.57166216$

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

---->

$su (4.8) = 0.39460211$

$M_u = MR_c (4.15) = 1.2308E+009$

$u = su (4.1) = 7.4763506E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu2-

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

$$\mu = 7.4763506E-005$$

$$Mu = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464812$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

$$f_x = 0.03787432$$

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

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

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

$$a_f = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1760.00$$

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

$$A_{sec} \text{ (section area)} = 262500.00$$

$$\text{psh,y ((5.4d), TBDY)} = \text{Lstir} \cdot \text{Astir} / (\text{Asec} \cdot \text{s}) = 0.00526591$$

$$\text{Lstir (Length of stirrups along X)} = 1360.00$$

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

$$\text{Asec (section area)} = 262500.00$$

$$\text{s} = 100.00$$

$$\text{fywe} = 656.25$$

$$\text{fce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: cc} = 0.0050771$$

$$\text{c} = \text{confinement factor} = 1.30771$$

$$\text{y1} = 0.0025$$

$$\text{sh1} = 0.008$$

$$\text{ft1} = 787.50$$

$$\text{fy1} = 656.25$$

$$\text{su1} = 0.032$$

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

$$\text{lo/lou,min} = \text{lb/l_d} = 1.00$$

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

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

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

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

$$\text{with fs1} = \text{fs} = 656.25$$

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

$$\text{y2} = 0.0025$$

$$\text{sh2} = 0.008$$

$$\text{ft2} = 787.50$$

$$\text{fy2} = 656.25$$

$$\text{su2} = 0.032$$

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

$$\text{lo/lou,min} = \text{lb}/\text{lb,min} = 1.00$$

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

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

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

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

$$\text{with fs2} = \text{fs} = 656.25$$

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

$$\text{yv} = 0.0025$$

$$\text{shv} = 0.008$$

$$\text{ftv} = 787.50$$

$$\text{fyv} = 656.25$$

$$\text{suv} = 0.032$$

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

$$\text{lo/lou,min} = \text{lb}/\text{l}_d = 1.00$$

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

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

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

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

$$\text{with fsv} = \text{fs} = 656.25$$

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

$$1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.19051738$$

$$2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.19051738$$

$$\text{v} = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.41602774$$

and confined core properties:

$$\text{b} = 190.00$$

$$\text{d} = 677.00$$

$$\text{d}' = 13.00$$

$$\text{fcc (5A.2, TBDY)} = 31.38503$$

$$cc (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$$

$$2 = A_{s1,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$$

$$v = A_{s1,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$$

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

---->

$$su (4.8) = 0.39460211$$

$$\mu_u = M_{Rc} (4.15) = 1.2308E+009$$

$$u = su (4.1) = 7.4763506E-005$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 673185.175$

Calculation of Shear Strength at edge 1, $V_{r1} = 673185.175$

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

$$V_{Co10} = 673185.175$$

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

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

= 1 (normal-weight concrete)

$$f_c' = 24.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu_u = 0.48500011$$

$$V_u = 5.0286180E-008$$

$$d = 0.8 * h = 600.00$$

$$N_u = 9867.325$$

$$A_g = 187500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 659734.457$$

where:

$V_{s1} = 164933.614$ is calculated for section web, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

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

$$s/d = 0.50$$

$V_{s2} = 494800.843$ is calculated for section flange, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

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

$$s/d = 0.16666667$$

$$V_f ((11-3)-(11.4), ACI 440) = 372533.843$$

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

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

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

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

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

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

total thickness per orientation, $tf1 = NL*t/NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 707.00
 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: $Vs + Vf \leq 488161.625$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $Vr2 = 673185.175$
 $Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl*VColO$
 $VColO = 673185.175$
 $knl = 1$ (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)
 $fc' = 24.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $Mu = 0.48484922$
 $Vu = 5.0286180E-008$
 $d = 0.8*h = 600.00$
 $Nu = 9867.325$
 $Ag = 187500.00$
From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 659734.457$
where:

$Vs1 = 164933.614$ is calculated for section web, with:
 $d = 200.00$
 $Av = 157079.633$
 $fy = 525.00$
 $s = 100.00$

$Vs1$ is multiplied by $Col1 = 1.00$
 $s/d = 0.50$

$Vs2 = 494800.843$ is calculated for section flange, with:
 $d = 600.00$
 $Av = 157079.633$
 $fy = 525.00$
 $s = 100.00$

$Vs2$ is multiplied by $Col2 = 1.00$
 $s/d = 0.16666667$

Vf ((11-3)-(11.4), ACI 440) = 372533.843
 $f = 0.95$, for fully-wrapped sections

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

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

This later relation, considered as a function $Vf(\alpha)$, 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: $\alpha = 45^\circ = 90.00$

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

total thickness per orientation, $tf1 = NL*t/NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 707.00
 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: $Vs + Vf \leq 488161.625$
 $bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $Ecc = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -79021.292$

Shear Force, $V_2 = 3183.231$

Shear Force, $V_3 = -74.47086$

Axial Force, $F = -10230.902$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 2261.947$

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

-Middle: $As_{l,mid} = 2060.885$

Mean Diameter of Tension Reinforcement, $Db_L = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \gamma * u = 0.00698679$

$u = \gamma * u_p = 0.00698679$

- Calculation of γ -

$\gamma = (M_y * L_s / 3) / E_{eff} = 0.00579458$ ((4.29), Biskinis Phd))

$M_y = 6.3263E+008$

$L_s = MV$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1061.104
From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 3.8616E+013$
factor = 0.30
 $A_g = 262500.00$
 $f_c' = 24.00$
 $N = 10230.902$
 $E_c \cdot I_g = 1.2872E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 8.9410173E-006$
with $f_y = 525.00$
 $d = 507.00$
 $y = 0.42092554$
 $A = 0.04080236$
 $B = 0.02737367$
with $pt = 0.01784573$
 $pc = 0.00654344$
 $pv = 0.01625945$
 $N = 10230.902$
 $b = 250.00$
 $" = 0.08481262$
 $y_{comp} = 8.8492878E-006$
with f_c^* (12.3, (ACI 440)) = 24.15812
 $f_c = 24.00$
 $f_l = 0.56655003$
 $b = b_{max} = 750.00$
 $h = h_{max} = 550.00$
 $A_g = 262500.00$
 $g = pt + pc + pv = 0.04064862$
 $rc = 40.00$
 $A_e/A_c = 0.16554652$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 23025.204$
 $y = 0.42093589$
 $A = 0.04043492$
 $B = 0.02721993$
with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

- Calculation of p -

From table 10-8: $p = 0.00119221$

with:

- Columns controlled by inadequate development or splicing along the clear height because $I_b/I_d < 1$

shear control ratio $V_y E / V_{col} O E = 1.51499$

$d = 507.00$

$s = 0.00$

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

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

$L_{stir} = 1360.00$, 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

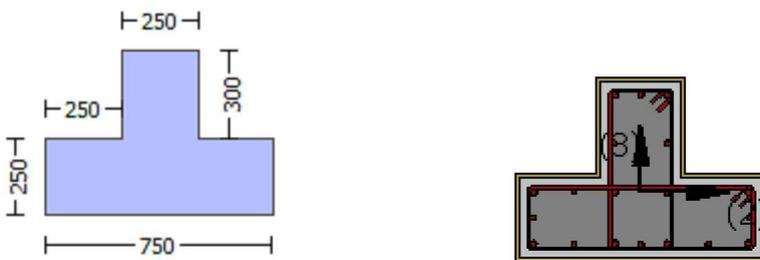
All these variables have already been given in Shear control ratio calculation.

NUD = 10230.902
 Ag = 262500.00
 fcE = 24.00
 fytE = fyE = 0.00
 pl = Area_Tot_Long_Rein/(b*d) = 0.04064862
 b = 250.00
 d = 507.00
 fcE = 24.00

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1
 At local axis: 2
 Integration Section: (b)

Calculation No. 7

column C1, Floor 1
 Limit State: Operational Level (data interpolation between analysis steps 1 and 2)
 Analysis: Uniform +X
 Check: Shear capacity VRd
 Edge: End
 Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1
 At local axis: 3
 Integration Section: (b)
 Section Type: rctcs

Constant Properties

Knowledge Factor, = 1.00
 Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.
 Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Primary Member: Concrete Strength, fc = fc_lower_bound = 16.00
 Existing material of Primary Member: Steel Strength, fs = fs_lower_bound = 420.00

Concrete Elasticity, $E_c = 23025.204$

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, $f_c = f_{cm} = 24.00$

Existing material: Steel Strength, $f_s = f_{sm} = 525.00$

#####

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $E_{cc} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{o,min} = l_b/l_d \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -143917.896$

Shear Force, $V_a = 74.47086$

EDGE -B-

Bending Moment, $M_b = -79021.292$

Shear Force, $V_b = -74.47086$

BOTH EDGES

Axial Force, $F = -10230.902$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 2261.947$

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

-Middle: $A_{sl,mid} = 2060.885$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 384877.535$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 384877.535$

$V_{CoI} = 384877.535$

$k_n = 1.00$

$displacement_ductility_demand = 3.6620733E-006$

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

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

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

$M/Vd = 2.4116$

$\mu_u = 79021.292$

$V_u = 74.47086$

$d = 0.8 \cdot h = 440.00$

$N_u = 10230.902$

$A_g = 137500.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 422230.053$

where:

$V_{s1} = 290283.161$ is calculated for section web, with:

$d = 440.00$

$A_v = 157079.633$

$f_y = 420.00$

$s = 100.00$

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

$s/d = 0.22727273$

$V_{s2} = 131946.891$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 420.00$

$s = 100.00$

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

$s/d = 0.50$

V_f ((11-3)-(11.4), ACI 440) = 267149.446

$f = 0.95$, 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, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 507.00

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: $V_s + V_f \leq 292293.685$

$b_w = 250.00$

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 $\theta = 2.1220173E-008$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00579458$ ((4.29), Biskinis Phd)

$M_y = 6.3263E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1061.104

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 3.8616E+013$

factor = 0.30

$A_g = 262500.00$

$f_c' = 24.00$

$N = 10230.902$

$E_c \cdot I_g = 1.2872E+014$

Calculation of Yielding Moment M_y

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

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

$y_{ten} = 8.9410173E-006$

with $f_y = 525.00$
 $d = 507.00$
 $y = 0.42092554$
 $A = 0.04080236$
 $B = 0.02737367$
with $pt = 0.01784573$
 $pc = 0.00654344$
 $pv = 0.01625945$
 $N = 10230.902$
 $b = 250.00$
 $" = 0.08481262$
 $y_{comp} = 8.8492878E-006$
with $f_c^* (12.3, (ACI 440)) = 24.15812$
 $f_c = 24.00$
 $fl = 0.56655003$
 $b = b_{max} = 750.00$
 $h = h_{max} = 550.00$
 $Ag = 262500.00$
 $g = pt + pc + pv = 0.04064862$
 $rc = 40.00$
 $Ae/Ac = 0.16554652$
Effective FRP thickness, $t_f = NL*t*\cos(b1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 23025.204$
 $y = 0.42093589$
 $A = 0.04043492$
 $B = 0.02721993$
with $E_s = 200000.00$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

End Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 8

column C1, Floor 1

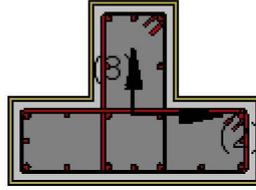
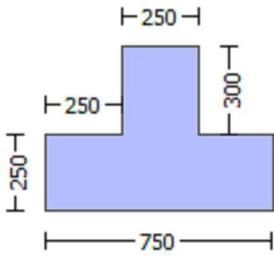
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 23025.204$
 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, $f_s = 1.25 \cdot f_{sm} = 656.25$

 Max Height, $H_{max} = 550.00$
 Min Height, $H_{min} = 250.00$
 Max Width, $W_{max} = 750.00$
 Min Width, $W_{min} = 250.00$
 Eccentricity, $Ecc = 250.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.30771
 Element Length, $L = 3000.00$

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

Stepwise Properties

At local axis: 3
 EDGE -A-
 Shear Force, $V_a = 0.00020794$
 EDGE -B-

Shear Force, $V_b = -0.00020794$

BOTH EDGES

Axial Force, $F = -9867.325$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{st,ten} = 2261.947$

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

-Middle: $A_{s,mid} = 2060.885$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.51499$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 645516.591$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 9.6827E+008$

$M_{u1+} = 9.6827E+008$, 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

$M_{u1-} = 8.4161E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 9.6827E+008$

$M_{u2+} = 9.6827E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 8.4161E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

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

$\phi_u = 2.0901588E-005$

$M_u = 9.6827E+008$

with full section properties:

$b = 250.00$

$d = 507.00$

$d' = 43.00$

$v = 0.0032437$

$N = 9867.325$

$f_c = 24.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01464812$

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

From (5.4b), TBDY: $\phi_{cu} = 0.01464812$

where ϕ_{cu} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07767542$

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

$\phi_{fx} = 0.03787432$

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

$\alpha_{f} = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$

$b_{max} = 750.00$

$h_{max} = 550.00$

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

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 748.2496$

$\phi_{fy} = 0.03787432$

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

$\alpha_{f} = 0.14946032$

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

$b_{max} = 750.00$

hmax = 550.00
From EC8 A.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 748.2496$

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

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$
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.
 $A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{\text{conf,min}} = 137025.00$ 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.
 $A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$
 L_{stir} (Length of stirrups along Y) = 1760.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 262500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$
 L_{stir} (Length of stirrups along X) = 1360.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 262500.00

s = 100.00
 $f_{ywe} = 656.25$
 $f_{ce} = 24.00$
From ((5.A5), TBDY), TBDY: $cc = 0.0050771$
c = confinement factor = 1.30771

$y1 = 0.0025$
 $sh1 = 0.008$
 $ft1 = 787.50$
 $fy1 = 656.25$
 $su1 = 0.032$

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

$l_o/l_{o,min} = l_b/l_d = 1.00$

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

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

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

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

with $fs1 = fs = 656.25$

with $Es1 = Es = 200000.00$

$y2 = 0.0025$
 $sh2 = 0.008$
 $ft2 = 787.50$
 $fy2 = 656.25$
 $su2 = 0.032$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

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

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

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

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

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

with $f_{s2} = f_s = 656.25$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$f_{y_v} = 656.25$

$s_{u_v} = 0.032$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

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

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

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

For calculation of $e_{s_{u_v,nominal}}$ and y_v, sh_v, ft_v, f_{y_v} , it is considered

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

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

with $f_{s_{y_v}} = f_s = 656.25$

with $E_{s_{y_v}} = E_s = 200000.00$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.48796927$

$2 = A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.17892207$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.44459423$

and confined core properties:

$b = 190.00$

$d = 477.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 31.38503$

$cc (5A.5, TBDY) = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.68244627$

$2 = A_{s2,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.2502303$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.62178438$

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 not satisfied

--->

Case/Assumption Rejected.

--->

New Case/Assumption: Unconfined full section - Spalling of concrete cover

' satisfies Eq. (4.4)

--->

$v < s_{y1}$ - LHS eq.(4.7) is not satisfied

--->

$v < v_{c,y1}$ - RHS eq.(4.6) is satisfied

--->

$c_u (4.10) = 0.43574957$

$M_{Rc} (4.17) = 8.0482E+008$

--->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o

- $N, 1, 2, v$ normalised to $b_o \cdot d_o$, instead of $b \cdot d$

- parameters of confined concrete, f_{cc}, cc , used in lieu of f_c, e_{cu}

--->

Subcase: Rupture of tension steel

--->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^*c,y2$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*c,y1$ - RHS eq.(4.6) is satisfied

--->

*cu (4.10) = 0.5092345

M_{Ro} (4.17) = 9.6827E+008

--->

u = cu (4.2) = 2.0901588E-005

Mu = M_{Ro}

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

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

u = 7.5354574E-005

Mu = 8.4161E+008

with full section properties:

b = 750.00

d = 507.00

d' = 43.00

v = 0.00108123

N = 9867.325

f_c = 24.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01464812

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

From (5.4b), TBDY: cu = 0.01464812

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.07767542

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

fx = 0.03787432

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

af = 0.14946032

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 39233.333

bmax = 750.00

hmax = 550.00

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

bw = 250.00

effective stress from (A.35), ff,e = 748.2496

fy = 0.03787432

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

af = 0.14946032

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 0.00

bmax = 750.00

hmax = 550.00

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

bw = 250.00

effective stress from (A.35), ff,e = 748.2496

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-A_{noConf})/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.35771528

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.

$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

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

$lo/lou,min = lb/l_d = 1.00$

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

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

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

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

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

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

$lo/lou,min = lb/l_{b,min} = 1.00$

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

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

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

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

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.05964069

2 = Asl,com/(b*d)*(fs2/fc) = 0.16265642

v = Asl,mid/(b*d)*(fsv/fc) = 0.14819808

and confined core properties:

b = 690.00

d = 477.00

d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

1 = Asl,ten/(b*d)*(fs1/fc) = 0.068904

2 = Asl,com/(b*d)*(fs2/fc) = 0.18791999

v = Asl,mid/(b*d)*(fsv/fc) = 0.17121599

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) = 0.16240824

Mu = MRc (4.15) = 8.4161E+008

u = su (4.1) = 7.5354574E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

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

u = 2.0901588E-005

Mu = 9.6827E+008

with full section properties:

b = 250.00

d = 507.00

d' = 43.00

v = 0.0032437

N = 9867.325

fc = 24.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01464812

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

From (5.4b), TBDY: cu = 0.01464812

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.07767542

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

fx = 0.03787432

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

af = 0.14946032

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 39233.333

bmax = 750.00
hmax = 550.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 748.2496$

 $fy = 0.03787432$
Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$
 $af = 0.14946032$
with Unconfined area = $((bmax-2R)^2 + (hmax-2R)^2)/3 = 0.00$
bmax = 750.00
hmax = 550.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 748.2496$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
 $fu,f = 1055.00$
 $Ef = 64828.00$
 $u,f = 0.015$
 $ase = \text{Max}(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.35771528$
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 = 188100.00 is the confined core 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 = 137025.00 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 = 95733.333 is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00406911$

 psh,x ((5.4d), TBDY) = $Lstir*Astir/(Asec*s) = 0.00406911$
Lstir (Length of stirrups along Y) = 1760.00
Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

 psh,y ((5.4d), TBDY) = $Lstir*Astir/(Asec*s) = 0.00526591$
Lstir (Length of stirrups along X) = 1360.00
Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

s = 100.00
 $fywe = 656.25$
fce = 24.00
From ((5.A5), TBDY), TBDY: $cc = 0.0050771$
c = confinement factor = 1.30771
 $y1 = 0.0025$
 $sh1 = 0.008$
 $ft1 = 787.50$
 $fy1 = 656.25$
 $su1 = 0.032$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou,min = lb/d = 1.00$
 $su1 = 0.4*esu1_nominal$ ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: $esu1_nominal = 0.08$,
For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs1 = fs = 656.25$
with $Es1 = Es = 200000.00$
 $y2 = 0.0025$

$sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lo_{min} = lb/lb_{min} = 1.00$
 $su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2_nominal} = 0.08$,
 For calculation of $esu_{2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 656.25$
 with $Es_2 = Es = 200000.00$
 $yv = 0.0025$
 $shv = 0.008$
 $ftv = 787.50$
 $fyv = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lo_{min} = lb/ld = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 656.25$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.48796927$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.17892207$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.44459423$
 and confined core properties:
 $b = 190.00$
 $d = 477.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.68244627$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.2502303$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.62178438$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y_2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is not satisfied
 --->
 Case/Assumption Rejected.
 --->
 New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)
 --->
 $v < s_{y_1}$ - LHS eq.(4.7) is not satisfied
 --->
 $v < v_{c,y_1}$ - RHS eq.(4.6) is satisfied
 --->
 $cu (4.10) = 0.43574957$
 $MRC (4.17) = 8.0482E+008$
 --->
 New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made
 - b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o

- N, 1, 2, v normalised to $b_0 \cdot d_0$, instead of $b \cdot d$
- parameters of confined concrete, f_{cc} , c_c , used in lieu of f_c , e_{cu}

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

* c_u (4.10) = 0.5092345

M R_o (4.17) = 9.6827E+008

---->

u = c_u (4.2) = 2.0901588E-005

Mu = M R_o

 Calculation of ratio l_b/l_d

 Adequate Lap Length: $l_b/l_d \geq 1$

 Calculation of Mu2-

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

u = 7.5354574E-005

Mu = 8.4161E+008

 with full section properties:

b = 750.00

d = 507.00

d' = 43.00

v = 0.00108123

N = 9867.325

f_c = 24.00

c_o (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} \cdot \text{Max}(c_u, c_c) = 0.01464812$

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

From (5.4b), TBDY: $c_u = 0.01464812$

w_e ((5.4c), TBDY) = $a_s \cdot \text{sh_min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$

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

 $f_x = 0.03787432$

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

$a_f = 0.14946032$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 39233.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 550.00$

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

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 748.2496$

 $f_y = 0.03787432$

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

$a_f = 0.14946032$

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

$b_{\text{max}} = 750.00$

hmax = 550.00
From EC8 A.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 748.2496$

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

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$
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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$
 L_{stir} (Length of stirrups along Y) = 1760.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 262500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$
 L_{stir} (Length of stirrups along X) = 1360.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 262500.00

s = 100.00
 $f_{ywe} = 656.25$
 $f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$
c = confinement factor = 1.30771

$y1 = 0.0025$
 $sh1 = 0.008$
 $ft1 = 787.50$
 $fy1 = 656.25$
 $su1 = 0.032$

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

$l_o/l_{o,min} = l_b/l_d = 1.00$

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

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

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

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

with $fs1 = fs = 656.25$

with $Es1 = Es = 200000.00$

$y2 = 0.0025$
 $sh2 = 0.008$
 $ft2 = 787.50$
 $fy2 = 656.25$
 $su2 = 0.032$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

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

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

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

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

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

with $f_{s2} = f_s = 656.25$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$f_{yv} = 656.25$

$s_{uv} = 0.032$

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

$l_o/l_{o,min} = l_b/d = 1.00$

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

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

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

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

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

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.05964069$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16265642$

v = $As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.14819808$

and confined core properties:

$b = 690.00$

$d = 477.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 31.38503$

$cc (5A.5, TBDY) = 0.0050771$

c = confinement factor = 1.30771

1 = $As_{l,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.068904$

2 = $As_{l,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.18791999$

v = $As_{l,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.17121599$

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

--->

$s_u (4.8) = 0.16240824$

$\mu_u = M_{Rc} (4.15) = 8.4161E+008$

u = $s_u (4.1) = 7.5354574E-005$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 426086.999$

Calculation of Shear Strength at edge 1, $V_{r1} = 426086.999$

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

$V_{Co10} = 426086.999$

$k_{nl} = 1$ (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)

$f_c' = 24.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 867.1065$

$V_u = 0.00020794$
 $d = 0.8 \cdot h = 440.00$
 $N_u = 9867.325$
 $A_g = 137500.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 527787.566$
 where:
 $V_{s1} = 362853.951$ is calculated for section web, with:
 $d = 440.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.22727273$
 $V_{s2} = 164933.614$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 V_f ((11-3)-(11.4), ACI 440) = 267149.446
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 507.00
 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: $V_s + V_f \leq 357985.191$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 426086.999$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 426086.999$
 $k_{nl} = 1$ (zero step-static loading)

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

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 24.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 867.1065$
 $V_u = 0.00020794$
 $d = 0.8 \cdot h = 440.00$
 $N_u = 9867.325$
 $A_g = 137500.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 527787.566$
 where:
 $V_{s1} = 362853.951$ is calculated for section web, with:
 $d = 440.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.22727273$
 $V_{s2} = 164933.614$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$

$f_y = 525.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 $V_f((11-3)-(11.4), ACI 440) = 267149.446$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 507.00
 $f_{fe}((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 357985.191$
 $bw = 250.00$

 End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rctcs

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 23025.204$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 656.25$
 #####
 Max Height, $H_{max} = 550.00$
 Min Height, $H_{min} = 250.00$
 Max Width, $W_{max} = 750.00$
 Min Width, $W_{min} = 250.00$
 Eccentricity, $Ecc = 250.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.30771
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o / l_{ou, min} > 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$

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

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 5.0286180E-008$
EDGE -B-
Shear Force, $V_b = -5.0286180E-008$
BOTH EDGES
Axial Force, $F = -9867.325$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1231.504$
-Compression: $As_{c,com} = 1231.504$
-Middle: $As_{c,mid} = 2689.203$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.21891$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 820555.407$
with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.2308E+009$
 $\mu_{u1+} = 1.2308E+009$, 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
 $\mu_{u1-} = 1.2308E+009$, 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
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.2308E+009$
 $\mu_{u2+} = 1.2308E+009$, 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
 $\mu_{u2-} = 1.2308E+009$, 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:
 $\mu_u = 7.4763506E-005$
 $\mu_u = 1.2308E+009$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.01464812$$

$$\mu_u \text{ ((5.4c), TBDY)} = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

$$f_x = 0.03787432$$

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

$$af = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$fy = 0.03787432$$

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

$$af = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $psh_{\text{min}} = \text{Min}(psh_x, psh_y) = 0.00406911$

$$psh_x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1760.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1360.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$fy_{we} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

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

$$lo/lou_{\text{min}} = lb/ld = 1.00$$

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

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

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

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

with $f_{s1} = f_s = 656.25$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 656.25$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19051738$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.19051738$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.41602774$
 and confined core properties:
 $b = 190.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.26178921$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.26178921$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.57166216$
 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
 --->
 $su (4.8) = 0.39460211$
 $Mu = MR_c (4.15) = 1.2308E+009$
 $u = su (4.1) = 7.4763506E-005$

 Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu_1 -

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

$$\mu = 7.4763506E-005$$

$$\mu_u = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } \mu_u: \mu_u = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.01464812$$

$$\mu_c \text{ ((5.4c), TBDY) } = \alpha * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

$$f_x = 0.03787432$$

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

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

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

$$\alpha_f = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00406911$$

$$\text{psh}_x \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 1760.00$$

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

$$A_{\text{sec}} \text{ (section area) } = 262500.00$$

$$\text{psh}_y \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 1360.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

s = 100.00

fywe = 656.25

fce = 24.00

From ((5.A.5), TBDY), TBDY: cc = 0.0050771

c = confinement factor = 1.30771

y1 = 0.0025

sh1 = 0.008

ft1 = 787.50

fy1 = 656.25

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 787.50

fy2 = 656.25

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es2 = Es = 200000.00

yv = 0.0025

shv = 0.008

ftv = 787.50

fyv = 656.25

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19051738

2 = Asl,com/(b*d)*(fs2/fc) = 0.19051738

v = Asl,mid/(b*d)*(fsv/fc) = 0.41602774

and confined core properties:

b = 190.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$$

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

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

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

--->
 μ (4.8) = 0.39460211

$$\mu = M_{Rc} \text{ (4.15)} = 1.2308E+009$$

$$u = \mu \text{ (4.1)} = 7.4763506E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{2+}

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

$$u = 7.4763506E-005$$

$$\mu = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_c) = 0.01464812$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01464812$$

$$\mu \text{ (5.4c), TBDY} = a_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

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

 $f_x = 0.03787432$

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

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

 $f_y = 0.03787432$

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

$$a_f = 0.14946032$$

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

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

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

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

 $R = 40.00$

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

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

$$E_f = 64828.00$$

u,f = 0.015

ase = $\text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_d = 1.00$

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

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

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

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

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

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

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

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

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

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$suv = 0.032$

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

$l_0/l_{0,min} = l_b/l_d = 1.00$

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

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

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

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

γ_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19051738$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.19051738$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.41602774$

and confined core properties:

$b = 190.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 31.38503$

$cc (5A.5, TBDY) = 0.0050771$

$c =$ confinement factor $= 1.30771$

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.26178921$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.26178921$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.57166216$

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

$s_u (4.8) = 0.39460211$

$M_u = M_{Rc} (4.15) = 1.2308E+009$

$u = s_u (4.1) = 7.4763506E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2} -

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

$u = 7.4763506E-005$

$M_u = 1.2308E+009$

with full section properties:

$b = 250.00$

$d = 707.00$

$d' = 43.00$

$v = 0.0023261$

$N = 9867.325$

$f_c = 24.00$

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

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, cc) = 0.01464812$

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

From (5.4b), TBDY: $c_u = 0.01464812$

$w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$

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

$f_x = 0.03787432$

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

$$af = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$fy = 0.03787432$$

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

$$af = 0.14946032$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

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

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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

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

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$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$$psh_{\text{min}} = \text{Min}(psh_x, psh_y) = 0.00406911$$

$$psh_x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1760.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1360.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$fy_{we} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

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

$$lo/lou_{\text{min}} = lb/ld = 1.00$$

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

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

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

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

$$\text{with } fs1 = fs = 656.25$$

with $E_s1 = E_s = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 1.00$
 $su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2_nominal} = 0.08$,
 For calculation of $esu_{2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 656.25$
 with $E_s2 = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.19051738$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.19051738$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.41602774$
 and confined core properties:
 $b = 190.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.26178921$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.26178921$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.57166216$
 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
 --->
 $su (4.8) = 0.39460211$
 $Mu = MRc (4.15) = 1.2308E+009$
 $u = su (4.1) = 7.4763506E-005$

 Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 673185.175$

Calculation of Shear Strength at edge 1, $Vr1 = 673185.175$

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

$VColO = 673185.175$

$knl = 1$ (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)

$fc' = 24.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.48500011$

$\nu_u = 5.0286180E-008$

$d = 0.8 * h = 600.00$

$Nu = 9867.325$

$Ag = 187500.00$

From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 659734.457$

where:

$Vs1 = 164933.614$ is calculated for section web, with:

$d = 200.00$

$Av = 157079.633$

$fy = 525.00$

$s = 100.00$

$Vs1$ is multiplied by $Col1 = 1.00$

$s/d = 0.50$

$Vs2 = 494800.843$ is calculated for section flange, with:

$d = 600.00$

$Av = 157079.633$

$fy = 525.00$

$s = 100.00$

$Vs2$ is multiplied by $Col2 = 1.00$

$s/d = 0.16666667$

Vf ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$dfv = d$ (figure 11.2, ACI 440) = 707.00

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: $Vs + Vf \leq 488161.625$

$bw = 250.00$

Calculation of Shear Strength at edge 2, $Vr2 = 673185.175$

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

$VColO = 673185.175$

$knl = 1$ (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)

$fc' = 24.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.48484922$

$\nu_u = 5.0286180E-008$

$d = 0.8 * h = 600.00$

$Nu = 9867.325$

Ag = 187500.00
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 659734.457$

where:

$V_{s1} = 164933.614$ is calculated for section web, with:

d = 200.00

Av = 157079.633

fy = 525.00

s = 100.00

V_{s1} is multiplied by Col1 = 1.00

s/d = 0.50

$V_{s2} = 494800.843$ is calculated for section flange, with:

d = 600.00

Av = 157079.633

fy = 525.00

s = 100.00

V_{s2} is multiplied by Col2 = 1.00

s/d = 0.16666667

Vf ((11-3)-(11.4), ACI 440) = 372533.843

f = 0.95, for fully-wrapped sections

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

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

This later relation, considered as a function $V_f(\alpha, \theta)$, 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

dfv = d (figure 11.2, ACI 440) = 707.00

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

Ef = 64828.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.01

From (11-11), ACI 440: $V_s + V_f \leq 488161.625$

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\phi = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $E_{cc} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_b/d >= 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 108875.895$
Shear Force, $V_2 = 3183.231$
Shear Force, $V_3 = -74.47086$
Axial Force, $F = -10230.902$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1231.504$
-Compression: $A_{sl,com} = 1231.504$
-Middle: $A_{sl,mid} = 2689.203$
Mean Diameter of Tension Reinforcement, $D_bL = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.00336155$
 $u = y + p = 0.00336155$

- Calculation of y -

 $y = (M_y * L_s / 3) / E_{eff} = 0.00103479$ ((4.29), Biskinis Phd))
 $M_y = 6.5616E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 6.3409E+013$
factor = 0.30
Ag = 262500.00
fc' = 24.00
N = 10230.902
Ec*Ig = 2.1136E+014

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 5.4983477E-006$
with $f_y = 525.00$
 $d = 707.00$
 $y = 0.32472963$
 $A = 0.02925997$
 $B = 0.01557156$
with $pt = 0.00696749$
 $pc = 0.00696749$
 $pv = 0.01521473$
 $N = 10230.902$

$b = 250.00$
 $\nu = 0.06082037$
 $y_{comp} = 8.2387023E-006$
 with f_c^* (12.3, (ACI 440)) = 24.16756
 $f_c = 24.00$
 $f_l = 0.56655003$
 $b = b_{max} = 750.00$
 $h = h_{max} = 550.00$
 $A_g = 262500.00$
 $g = p_t + p_c + p_v = 0.02914971$
 $r_c = 40.00$
 $A_e/A_c = 0.17542991$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 23025.204$
 $y = 0.32435731$
 $A = 0.02899653$
 $B = 0.01546131$
 with $E_s = 200000.00$

 Calculation of ratio l_b/d

 Adequate Lap Length: $l_b/d \geq 1$

 - Calculation of p -

 From table 10-8: $p = 0.00232676$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/d < 1$

shear control ratio $V_y E / V_{col} O E = 1.21891$

$d = 707.00$

$s = 0.00$

$t = A_v / (b w * s) + 2 * t_f / b w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b w * (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1760.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 * t_f / b w * (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 * t_f / b w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$N_{UD} = 10230.902$

$A_g = 262500.00$

$f_{cE} = 24.00$

$f_{ytE} = f_{ylE} = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02914971$

$b = 250.00$

$d = 707.00$

$f_{cE} = 24.00$

 End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 9

column C1, Floor 1

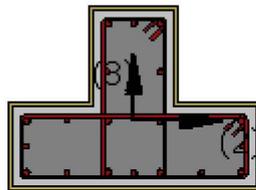
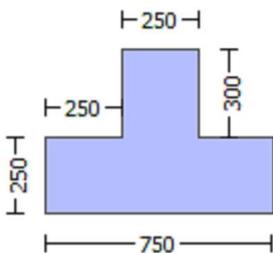
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 23025.204$

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, $f_c = f_{cm} = 24.00$

Existing material: Steel Strength, $f_s = f_{sm} = 525.00$

#####

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $Ecc = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{o,u,min} = l_b/l_d \geq 1$)
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, $M_a = -7.7550E+006$
Shear Force, $V_a = -2555.206$
EDGE -B-
Bending Moment, $M_b = 87395.69$
Shear Force, $V_b = 2555.206$
BOTH EDGES
Axial Force, $F = -10159.171$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1231.504$
-Compression: $A_{sl,com} = 1231.504$
-Middle: $A_{sl,mid} = 2689.203$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = *V_n = 474325.583$
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI} = 474325.583$
 $V_{CoI} = 474325.583$
 $knl = 1.00$
 $displacement_ductility_demand = 0.00503454$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*VF'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 7.7550E+006$
 $V_u = 2555.206$
 $d = 0.8 * h = 600.00$
 $N_u = 10159.171$
 $A_g = 187500.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 527787.566$
where:
 $V_{s1} = 131946.891$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 395840.674$ is calculated for section flange, with:
 $d = 600.00$
 $A_v = 157079.633$

$f_y = 420.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.16666667$
 $V_f((11-3)-(11.4), ACI 440) = 372533.843$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 $\ln(11.3) \sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 707.00
 $f_{fe}((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 398582.298$
 $b_w = 250.00$

displacement ductility demand is calculated as δ / y

- Calculation of δ / y for END A -
for rotation axis 3 and integ. section (a)

From analysis, chord rotation $\theta = 5.2702918E-005$
 $y = (M_y * L_s / 3) / E_{eff} = 0.01046826$ ((4.29), Biskinis Phd)
 $M_y = 6.5614E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3034.966
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 6.3409E+013$
 $\text{factor} = 0.30$
 $A_g = 262500.00$
 $f_c' = 24.00$
 $N = 10159.171$
 $E_c * I_g = 2.1136E+014$

Calculation of Yielding Moment M_y

Calculation of δ and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 5.4982839E-006$
 with $f_y = 525.00$
 $d = 707.00$
 $y = 0.3247218$
 $A = 0.0292592$
 $B = 0.01557079$
 with $p_t = 0.00696749$
 $p_c = 0.00696749$
 $p_v = 0.01521473$
 $N = 10159.171$
 $b = 250.00$
 $\theta = 0.06082037$
 $y_{comp} = 8.2388357E-006$
 with $f_c' = 24.00$ (12.3, (ACI 440)) = 24.16756
 $f_c = 24.00$
 $f_l = 0.56655003$
 $b = b_{max} = 750.00$
 $h = h_{max} = 550.00$
 $A_g = 262500.00$
 $g = p_t + p_c + p_v = 0.02914971$

$r_c = 40.00$
 $A_e/A_c = 0.17542991$
Effective FRP thickness, $t_f = NL*t*\text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 23025.204$
 $y = 0.32435206$
 $A = 0.0289976$
 $B = 0.01546131$
with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

End Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 10

column C1, Floor 1

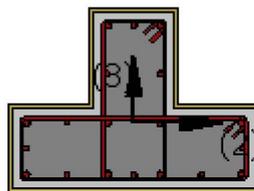
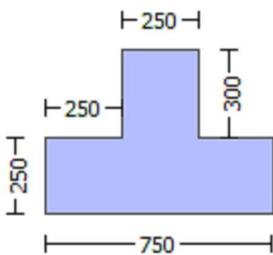
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rctcs

Constant Properties

```

Knowledge Factor,  $\phi = 1.00$ 
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$ 
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$ 
Concrete Elasticity,  $E_c = 23025.204$ 
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,  $f_s = 1.25 \cdot f_{sm} = 656.25$ 
#####
Max Height,  $H_{max} = 550.00$ 
Min Height,  $H_{min} = 250.00$ 
Max Width,  $W_{max} = 750.00$ 
Min Width,  $W_{min} = 250.00$ 
Eccentricity,  $Ecc = 250.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.30771
Element Length,  $L = 3000.00$ 
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou, min} > 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $NoDir = 1$ 
Fiber orientations,  $bi = 0.00^\circ$ 
Number of layers,  $NL = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
At local axis: 3
EDGE -A-
Shear Force,  $V_a = 0.00020794$ 
EDGE -B-
Shear Force,  $V_b = -0.00020794$ 
BOTH EDGES
Axial Force,  $F = -9867.325$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $A_{st} = 0.00$ 
-Compression:  $A_{sc} = 5152.212$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $A_{st, ten} = 2261.947$ 
-Compression:  $A_{sl, com} = 829.3805$ 
-Middle:  $A_{sl, mid} = 2060.885$ 
-----
-----

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.51499$ 
Member Controlled by Shear ( $V_e/V_r > 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 645516.591$ 
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 9.6827E+008$ 
 $M_{u1+} = 9.6827E+008$ , 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
 $M_{u1-} = 8.4161E+008$ , 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 9.6827E+008$$

$M_{u2+} = 9.6827E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 8.4161E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 2.0901588E-005$$

$$M_u = 9.6827E+008$$

with full section properties:

$$b = 250.00$$

$$d = 507.00$$

$$d' = 43.00$$

$$v = 0.0032437$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$\omega (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \phi_{cu} = 0.01464812$$

$$\phi_{ve} \text{ ((5.4c), TB DY) } = a_{se} * \phi_{sh, \min} * f_{yve} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07767542$$

where $\phi_f = a_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.03787432$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$\phi_{fy} = 0.03787432$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00406911$$

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00406911$$

$$Lstir (\text{Length of stirrups along } Y) = 1760.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 262500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00526591$$

$$Lstir (\text{Length of stirrups along } X) = 1360.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 262500.00$$

$$s = 100.00$$

$$fywe = 656.25$$

$$fce = 24.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/d = 1.00$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 656.25$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 787.50$$

$$fy2 = 656.25$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 1.00$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 656.25$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 787.50$$

$$fyv = 656.25$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/d = 1.00$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 656.25$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.48796927$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.17892207$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.44459423$$

and confined core properties:

$$b = 190.00$$

$$d = 477.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 31.38503$$

$$c_c (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.68244627$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.2502303$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.62178438$$

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 not satisfied

---->

Case/Assumption Rejected.

---->

New Case/Assumption: Unconfined full section - Spalling of concrete cover

' satisfies Eq. (4.4)

---->

$v < s_{y1}$ - LHS eq.(4.7) is not satisfied

---->

$v < v_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

$$c_u (4.10) = 0.43574957$$

$$M_{Rc} (4.17) = 8.0482E+008$$

---->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o

- $N, 1, 2, v$ normalised to b_o*d_o , instead of $b*d$

- - parameters of confined concrete, f_{cc}, c_c , used in lieu of f_c, c_c

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

$$^*c_u (4.10) = 0.5092345$$

$$M_{Ro} (4.17) = 9.6827E+008$$

---->

$$u = c_u (4.2) = 2.0901588E-005$$

$$M_u = M_{Ro}$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u1} -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 7.5354574E-005$$

$$Mu = 8.4161E+008$$

with full section properties:

$$b = 750.00$$

$$d = 507.00$$

$$d' = 43.00$$

$$v = 0.00108123$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01464812$$

$$\omega_e \text{ ((5.4c), TBDY) } = a_{se} * s_{h,\min} * f_{y\omega_e} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07767542$$

where $\phi = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$\phi_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$$

$$p_{sh,x} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 1760.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 262500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 1360.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 262500.00$$

$s = 100.00$
 $fy_{we} = 656.25$
 $f_{ce} = 24.00$
 From ((5.A.5), TBDY), TBDY: $cc = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $y_1 = 0.0025$
 $sh_1 = 0.008$
 $ft_1 = 787.50$
 $fy_1 = 656.25$
 $su_1 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 1.00$
 $su_1 = 0.4 * esu_1 \text{ nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_1 \text{ nominal} = 0.08$,
 For calculation of $esu_1 \text{ nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 656.25$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/lb, \min = 1.00$
 $su_2 = 0.4 * esu_2 \text{ nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_2 \text{ nominal} = 0.08$,
 For calculation of $esu_2 \text{ nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 656.25$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, \min = lb/ld = 1.00$
 $suv = 0.4 * esuv \text{ nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv \text{ nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv \text{ nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 656.25$
 with $Esv = Es = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.05964069$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.16265642$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.14819808$
 and confined core properties:
 $b = 690.00$
 $d = 477.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.068904$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.18791999$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.17121599$$

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

--->

$$s_u(4.8) = 0.16240824$$

$$M_u = M_{Rc}(4.15) = 8.4161E+008$$

$$u = s_u(4.1) = 7.5354574E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 2.0901588E-005$$

$$M_u = 9.6827E+008$$

with full section properties:

$$b = 250.00$$

$$d = 507.00$$

$$d' = 43.00$$

$$v = 0.0032437$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$\alpha(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \alpha_c = 0.01464812$$

$$\alpha_{we} \text{ ((5.4c), TBDY) } = \alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

where $f = \alpha * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.35771528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/ld = 1.00$

$su_1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/lb,min = 1.00$

$su_2 = 0.4 * esu2_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 γ_v , shv,ftv,fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 γ_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 $fsv = fs = 656.25$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.48796927$
 $2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.17892207$
 $v = Asl_{mid}/(b*d)*(fsv/fc) = 0.44459423$

and confined core properties:

$b = 190.00$
 $d = 477.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.68244627$
 $2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.2502303$
 $v = Asl_{mid}/(b*d)*(fsv/fc) = 0.62178438$

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 not satisfied

---->

Case/Assumption Rejected.

---->

New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)

---->

$v < s_{y1}$ - LHS eq.(4.7) is not satisfied

---->

$v < v_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

$cu (4.10) = 0.43574957$
 $MRc (4.17) = 8.0482E+008$

---->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
- $N, 1, 2, v$ normalised to b_o*d_o , instead of $b*d$
- parameters of confined concrete, f_{cc}, cc , used in lieu of f_c, c

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

$*cu (4.10) = 0.5092345$
 $MRO (4.17) = 9.6827E+008$

---->

$u = cu (4.2) = 2.0901588E-005$
 $Mu = MRO$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_2

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 7.5354574E-005$

$\mu_2 = 8.4161E+008$

with full section properties:

$b = 750.00$

$d = 507.00$

$d' = 43.00$

$v = 0.00108123$

$N = 9867.325$

$f_c = 24.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of μ_2 : $\mu_2^* = \text{shear_factor} * \text{Max}(\mu_2, \mu_c) = 0.01464812$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_2 = 0.01464812$

μ_2 ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{, \min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$

where $f_x = \alpha_f * \rho_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.03787432$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.14946032$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$

$b_{\max} = 750.00$

$h_{\max} = 550.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 748.2496$

$f_y = 0.03787432$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.14946032$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$

$b_{\max} = 750.00$

$h_{\max} = 550.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 748.2496$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{2,f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00406911$$

$$psh,x ((5.4d), \text{TBDY}) = Lstir * Astir / (Asec * s) = 0.00406911$$

$$Lstir (\text{Length of stirrups along Y}) = 1760.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 262500.00$$

$$psh,y ((5.4d), \text{TBDY}) = Lstir * Astir / (Asec * s) = 0.00526591$$

$$Lstir (\text{Length of stirrups along X}) = 1360.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 262500.00$$

$$s = 100.00$$

$$fywe = 656.25$$

$$fce = 24.00$$

$$\text{From } ((5.A5), \text{TBDY}), \text{TBDY: } cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 656.25$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 787.50$$

$$fy2 = 656.25$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 1.00$$

$$su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 656.25$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 787.50$$

$$fyv = 656.25$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 656.25$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.05964069$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.16265642$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.14819808$$

and confined core properties:

$$b = 690.00$$

$$d = 477.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 31.38503$$

$$c_c (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.068904$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.18791999$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.17121599$$

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

--->

$$s_u (4.8) = 0.16240824$$

$$M_u = M_{Rc} (4.15) = 8.4161E+008$$

$$u = s_u (4.1) = 7.5354574E-005$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 426086.999$

Calculation of Shear Strength at edge 1, $V_{r1} = 426086.999$

$$V_{r1} = V_{CoI} ((10.3), ASCE 41-17) = k_{nl} * V_{CoI0}$$

$$V_{CoI0} = 426086.999$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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 (normal-weight concrete)

$$f_c' = 24.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 867.1065$$

$$V_u = 0.00020794$$

$$d = 0.8 * h = 440.00$$

$$N_u = 9867.325$$

$$A_g = 137500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 527787.566$$

where:

$V_{s1} = 362853.951$ is calculated for section web, with:

$$d = 440.00$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

V_{s1} is multiplied by $Col1 = 1.00$

$$s/d = 0.22727273$$

$V_{s2} = 164933.614$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

V_{s2} is multiplied by $Col2 = 1.00$

$$s/d = 0.50$$

$$V_f ((11-3)-(11.4), ACI 440) = 267149.446$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $tf1 = NL * t / \text{NoDir} = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 507.00

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: $V_s + V_f \leq 357985.191$

$bw = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 426086.999$

$V_{r2} = V_{Co1}$ ((10.3), ASCE 41-17) = $kn1 * V_{Co10}$

$V_{Co10} = 426086.999$

$kn1 = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs + f*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

$\gamma_c = 1$ (normal-weight concrete)

$f_c' = 24.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 867.1065$

$V_u = 0.00020794$

$d = 0.8 * h = 440.00$

$N_u = 9867.325$

$A_g = 137500.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 527787.566$

where:

$V_{s1} = 362853.951$ is calculated for section web, with:

$d = 440.00$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.22727273$

$V_{s2} = 164933.614$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.50$

V_f ((11-3)-(11.4), ACI 440) = 267149.446

$f = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $tf1 = NL * t / \text{NoDir} = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 507.00

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: $V_s + V_f \leq 357985.191$

$bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
Concrete Elasticity, $E_c = 23025.204$
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, $f_s = 1.25 \cdot f_{sm} = 656.25$

Max Height, $H_{max} = 550.00$
Min Height, $H_{min} = 250.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 250.00$
Eccentricity, $Ecc = 250.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.30771
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} > 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 5.0286180E-008$
EDGE -B-
Shear Force, $V_b = -5.0286180E-008$
BOTH EDGES
Axial Force, $F = -9867.325$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 1231.504$

-Compression: $Asl,com = 1231.504$
-Middle: $Asl,mid = 2689.203$

Calculation of Shear Capacity ratio , $Ve/Vr = 1.21891$

Member Controlled by Shear ($Ve/Vr > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $Ve = (Mpr1 + Mpr2)/ln = 820555.407$

with

$Mpr1 = \text{Max}(Mu1+, Mu1-) = 1.2308E+009$

$Mu1+ = 1.2308E+009$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu1- = 1.2308E+009$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$Mpr2 = \text{Max}(Mu2+, Mu2-) = 1.2308E+009$

$Mu2+ = 1.2308E+009$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$Mu2- = 1.2308E+009$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of $Mu1+$

Calculation of ultimate curvature ϵ_u according to 4.1, Biskinis/Fardis 2013:

$\epsilon_u = 7.4763506E-005$

$Mu = 1.2308E+009$

with full section properties:

$b = 250.00$

$d = 707.00$

$d' = 43.00$

$v = 0.0023261$

$N = 9867.325$

$f_c = 24.00$

$\alpha_{co} (5A.5, TBDY) = 0.002$

Final value of ϵ_{cu} : $\epsilon_{cu}^* = \text{shear_factor} * \text{Max}(\epsilon_{cu}, \epsilon_{cc}) = 0.01464812$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\epsilon_{cu} = 0.01464812$

$\epsilon_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\epsilon_{fx}, \epsilon_{fy}) = 0.07767542$

where $f = \alpha_f * \rho_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\epsilon_{fx} = 0.03787432$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$

$b_{max} = 750.00$

$h_{max} = 550.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 748.2496$

$\epsilon_{fy} = 0.03787432$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 750.00$

$h_{max} = 550.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 748.2496$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.35771528$$

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.

$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00406911$$

$$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1760.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 262500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1360.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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.

$$\text{with } fs_1 = fs = 656.25$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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.

$$\text{with } fs_2 = fs = 656.25$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19051738

2 = Asl,com/(b*d)*(fs2/fc) = 0.19051738

v = Asl,mid/(b*d)*(fsv/fc) = 0.41602774

and confined core properties:

b = 190.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

1 = Asl,ten/(b*d)*(fs1/fc) = 0.26178921

2 = Asl,com/(b*d)*(fs2/fc) = 0.26178921

v = Asl,mid/(b*d)*(fsv/fc) = 0.57166216

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) = 0.39460211

Mu = MRc (4.15) = 1.2308E+009

u = su (4.1) = 7.4763506E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 7.4763506E-005

Mu = 1.2308E+009

with full section properties:

b = 250.00

d = 707.00

d' = 43.00

v = 0.0023261

N = 9867.325

fc = 24.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01464812

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01464812

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.07767542

where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.03787432

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$

$b_{max} = 750.00$

$h_{max} = 550.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff,e = 748.2496$

$f_y = 0.03787432$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 750.00$

$h_{max} = 550.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff,e = 748.2496$

$R = 40.00$

Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.35771528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

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$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

$s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

c = confinement factor = 1.30771

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 787.50$

$fy1 = 656.25$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/ld = 1.00$

$su1 = 0.4*esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s1} = f_s = 656.25$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 656.25$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.19051738$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.19051738$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.41602774$
 and confined core properties:
 $b = 190.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$
 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
 --->
 $su (4.8) = 0.39460211$
 $Mu = MR_c (4.15) = 1.2308E+009$
 $u = su (4.1) = 7.4763506E-005$

 Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 7.4763506E-005$$

$$\mu_u = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.01464812$$

$$\mu_c \text{ ((5.4c), TBDY) } = \alpha * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

where $f = \alpha * \rho_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00406911$$

$$\text{psh}_x \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 1760.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 262500.00$$

$$\text{psh}_y \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 1360.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

s = 100.00
fywe = 656.25
fce = 24.00

From ((5.A.5), TBDY), TBDY: cc = 0.0050771
c = confinement factor = 1.30771

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19051738

2 = Asl,com/(b*d)*(fs2/fc) = 0.19051738

v = Asl,mid/(b*d)*(fsv/fc) = 0.41602774

and confined core properties:

b = 190.00
d = 677.00
d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$$

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

--->

$$s_u(4.8) = 0.39460211$$

$$\mu_u = M_{Rc}(4.15) = 1.2308E+009$$

$$u = s_u(4.1) = 7.4763506E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{u2}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 7.4763506E-005$$

$$\mu_u = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01464812$$

$$w_e(5.4c, TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

u,f = 0.015

ase = $\text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 * esu_{2,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2 , sh_2 , ft_2 , fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_0/l_{ou,min} = l_b/l_d = 1.00$

$s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv_nominal}$ and γ_v , sh_v, ft_v, f_{y_v} , it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_1 , sh_1, ft_1, f_{y_1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19051738$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.19051738$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.41602774$

and confined core properties:

$b = 190.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 31.38503$

$cc (5A.5, TBDY) = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.26178921$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.26178921$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.57166216$

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

$s_u (4.8) = 0.39460211$

$M_u = M_{Rc} (4.15) = 1.2308E+009$

$u = s_u (4.1) = 7.4763506E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 673185.175$

Calculation of Shear Strength at edge 1, $V_{r1} = 673185.175$

$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} * V_{Co10}$

$V_{Co10} = 673185.175$

$k_{nl} = 1$ (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)

$f_c' = 24.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 0.48500011$

$V_u = 5.0286180E-008$

$d = 0.8 * h = 600.00$

$N_u = 9867.325$

$A_g = 187500.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 659734.457$

where:

$V_{s1} = 164933.614$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 525.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 494800.843$ is calculated for section flange, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.16666667$
 V_f ((11-3)-(11.4), ACI 440) = 372533.843
 $f = 0.95$, 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: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 707.00
 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: $V_s + V_f \leq 488161.625$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 673185.175$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$
 $V_{Col0} = 673185.175$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+ f * V_f}$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\rho = 1$ (normal-weight concrete)
 $f_c' = 24.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/d = 2.00$
 $\mu_u = 0.48484922$
 $V_u = 5.0286180E-008$
 $d = 0.8 * h = 600.00$
 $N_u = 9867.325$
 $A_g = 187500.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 659734.457$
 where:
 $V_{s1} = 164933.614$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 494800.843$ is calculated for section flange, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.16666667$
 V_f ((11-3)-(11.4), ACI 440) = 372533.843
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, 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: $b_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 488161.625$

$b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $E_{cc} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b / l_d > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $\text{NoDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -115353.03$

Shear Force, $V_2 = -2555.206$

Shear Force, $V_3 = 59.77842$

Axial Force, $F = -10159.171$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{st,ten} = 2261.947$

-Compression: $A_{sc,com} = 829.3805$

-Middle: $A_{st,mid} = 2060.885$

Mean Diameter of Tension Reinforcement, $D_bL = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $\phi_{u,R} = \phi_u = 0.04934461$

$\phi_u = \phi_y + \phi_p = 0.04934461$

- Calculation of ϕ_y -

$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.01053787$ ((4.29), Biskinis Phd))

$M_y = 6.3264E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1929.677

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 3.8616E+013$

factor = 0.30

$A_g = 262500.00$

$f_c' = 24.00$

$N = 10159.171$

$E_c * I_g = 1.2872E+014$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

$\phi_y = \text{Min}(\phi_{y,ten}, \phi_{y,com})$

$\phi_{y,ten} = 8.9409093E-006$

with $f_y = 525.00$

$d = 507.00$

$\phi_y = 0.42091854$

$A = 0.04080128$

$B = 0.02737259$

with $p_t = 0.01784573$

$p_c = 0.00654344$

$p_v = 0.01625945$

$N = 10159.171$

$b = 250.00$

$\phi_y = 0.08481262$

$\phi_{y,comp} = 8.8494370E-006$

with f_c^* (12.3, (ACI 440)) = 24.15812

$f_c = 24.00$

$f_l = 0.56655003$

$b = b_{max} = 750.00$

$h = h_{max} = 550.00$

$A_g = 262500.00$

$g = p_t + p_c + p_v = 0.04064862$

$r_c = 40.00$

$A_e / A_c = 0.16554652$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 23025.204$

$\phi_y = 0.4209288$

$A = 0.04043641$

$B = 0.02721993$

with $E_s = 200000.00$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of ρ -

From table 10-8: $\rho = 0.03880673$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/d < 1$

shear control ratio $V_{yE}/V_{CoIE} = 1.51499$

$d = 507.00$

$s = 0.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1360.00$, 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.

$NUD = 10159.171$

$A_g = 262500.00$

$f_{cE} = 24.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.04064862$

$b = 250.00$

$d = 507.00$

$f_{cE} = 24.00$

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 11

column C1, Floor 1

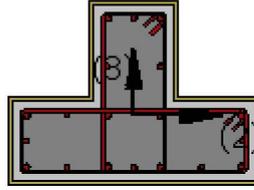
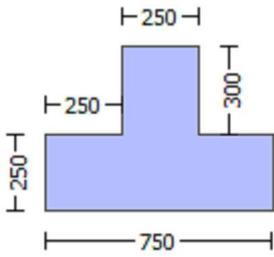
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 23025.204$

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, $f_c = f_{cm} = 24.00$

Existing material: Steel Strength, $f_s = f_{sm} = 525.00$

#####

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $Ecc = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} = l_b/d >= 1$)

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, $M_a = -115353.03$

Shear Force, $V_a = 59.77842$
EDGE -B-
Bending Moment, $M_b = -63602.127$
Shear Force, $V_b = -59.77842$
BOTH EDGES
Axial Force, $F = -10159.171$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{s,ten} = 2261.947$
-Compression: $A_{s,com} = 829.3805$
-Middle: $A_{s,mid} = 2060.885$
Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 348105.423$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 348105.423$
 $V_{CoI} = 348105.423$
 $k_n = 1.00$
displacement_ductility_demand = 0.00099738

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} = \phi V_f$ '
where V_f is the contribution of FRPs ((11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 115353.03$
 $V_u = 59.77842$
 $d = 0.8 \cdot h = 440.00$
 $N_u = 10159.171$
 $A_g = 137500.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 422230.053$
where:
 $V_{s1} = 290283.161$ is calculated for section web, with:
 $d = 440.00$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.22727273$
 $V_{s2} = 131946.891$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 V_f ((11-3)-(11.4), ACI 440) = 267149.446
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 507.00
 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: $V_s + V_f \leq 292293.685$

bw = 250.00

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END A -
for rotation axis 2 and integ. section (a)

From analysis, chord rotation $\theta = 1.0510286E-005$
 $y = (M_y * L_s / 3) / E_{eff} = 0.01053787$ ((4.29), Biskinis Phd)
 $M_y = 6.3264E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1929.677
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 3.8616E+013$
factor = 0.30
 $A_g = 262500.00$
 $f_c' = 24.00$
 $N = 10159.171$
 $E_c * I_g = 1.2872E+014$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 8.9409093E-006$
with $f_y = 525.00$
 $d = 507.00$
 $y = 0.42091854$
 $A = 0.04080128$
 $B = 0.02737259$
with $pt = 0.01784573$
 $pc = 0.00654344$
 $pv = 0.01625945$
 $N = 10159.171$
 $b = 250.00$
 $\alpha = 0.08481262$
 $y_{comp} = 8.8494370E-006$
with $f_c' (12.3, (ACI 440)) = 24.15812$
 $f_c = 24.00$
 $f_l = 0.56655003$
 $b = b_{max} = 750.00$
 $h = h_{max} = 550.00$
 $A_g = 262500.00$
 $g = pt + pc + pv = 0.04064862$
 $rc = 40.00$
 $A_e / A_c = 0.16554652$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 23025.204$
 $y = 0.4209288$
 $A = 0.04043641$
 $B = 0.02721993$
with $E_s = 200000.00$

Calculation of ratio l_b / d

Adequate Lap Length: $l_b / d \geq 1$

End Of Calculation of Shear Capacity for element: column TC1 of floor 1
At local axis: 3
Integration Section: (a)

Calculation No. 12

column C1, Floor 1

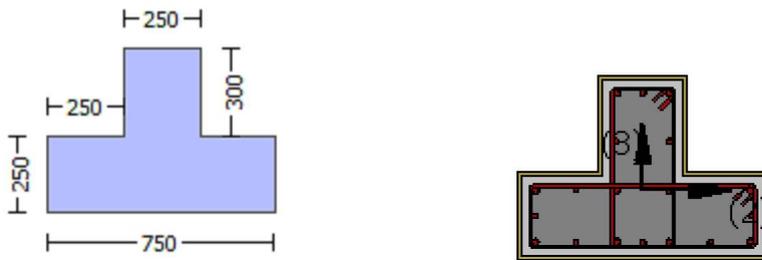
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

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, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $Ecc = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.30771

Element Length, $L = 3000.00$

Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou}, \min >= 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 0.00020794$
EDGE -B-
Shear Force, $V_b = -0.00020794$
BOTH EDGES
Axial Force, $F = -9867.325$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 2261.947$
-Compression: $A_{st,com} = 829.3805$
-Middle: $A_{st,mid} = 2060.885$

Calculation of Shear Capacity ratio , $V_e/V_r = 1.51499$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 645516.591$
with

$M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 9.6827E+008$

$Mu_{1+} = 9.6827E+008$, 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

$Mu_{1-} = 8.4161E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 9.6827E+008$

$Mu_{2+} = 9.6827E+008$, 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

$Mu_{2-} = 8.4161E+008$, 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:

$\phi_u = 2.0901588E-005$

$M_u = 9.6827E+008$

with full section properties:

$b = 250.00$

$d = 507.00$

$d' = 43.00$

$$v = 0.0032437$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01464812$$

$$\text{we (5.4c), TBDY) } = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1760.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 262500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1360.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$f_{y1} = 656.25$$

$$s_{u1} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_d = 1.00$$

$$s_{u1} = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,

For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, f_{y1} , it is considered
characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s1} = f_s = 656.25$$

$$\text{with } E_{s1} = E_s = 200000.00$$

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$f_{y2} = 656.25$$

$$s_{u2} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 1.00$$

$$s_{u2} = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,

For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, f_{y2} , it is considered
characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, f_{y2} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } f_{s2} = f_s = 656.25$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$f_{yv} = 656.25$$

$$s_{uv} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_d = 1.00$$

$$s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } f_{sv} = f_s = 656.25$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.48796927$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.17892207$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.44459423$$

and confined core properties:

$$b = 190.00$$

$$d = 477.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 31.38503$$

$$cc (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.68244627$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.2502303$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.62178438$$

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 not satisfied

--->

Case/Assumption Rejected.

--->

New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

--->

$v < s_y1$ - LHS eq.(4.7) is not satisfied

--->

$v < v_c y1$ - RHS eq.(4.6) is satisfied

--->

c_u (4.10) = 0.43574957

M_{Rc} (4.17) = 8.0482E+008

--->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o , d_o , d'_o
- N , 1 , 2 , v normalised to $b_o * d_o$, instead of $b * d$
- - parameters of confined concrete, f_{cc} , c_c , used in lieu of f_c , c_u

--->

Subcase: Rupture of tension steel

--->

$v^* < v^* s_y2$ - LHS eq.(4.5) is not satisfied

--->

$v^* < v^* s_c$ - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$v^* < v^* c_y2$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^* c_y1$ - RHS eq.(4.6) is satisfied

--->

$*c_u$ (4.10) = 0.5092345

M_{Ro} (4.17) = 9.6827E+008

--->

$u = c_u$ (4.2) = 2.0901588E-005

$M_u = M_{Ro}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of M_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 7.5354574E-005$

$M_u = 8.4161E+008$

with full section properties:

$b = 750.00$

$d = 507.00$

$d' = 43.00$

$v = 0.00108123$

$N = 9867.325$

$f_c = 24.00$

c_o (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01464812$

where $f = a_f * p_f * f_{fe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.03787432$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$

$b_{max} = 750.00$

$h_{max} = 550.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff,e = 748.2496$

$f_y = 0.03787432$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 750.00$

$h_{max} = 550.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff,e = 748.2496$

$R = 40.00$

Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.35771528$

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.

$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

$s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

c = confinement factor = 1.30771

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 787.50$

$fy1 = 656.25$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/ld = 1.00$

$su1 = 0.4*esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s1} = f_s = 656.25$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 656.25$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsy_v = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsy_v = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05964069$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.16265642$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.14819808$

and confined core properties:

$b = 690.00$
 $d = 477.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.068904$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.18791999$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.17121599$

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

--->
 $su (4.8) = 0.16240824$
 $Mu = MR_c (4.15) = 8.4161E+008$
 $u = su (4.1) = 7.5354574E-005$

 Calculation of ratio l_b/l_d

 Adequate Lap Length: $l_b/l_d \geq 1$

 Calculation of Mu_{2+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 2.0901588E-005$$

$$\mu = 9.6827E+008$$

with full section properties:

$$b = 250.00$$

$$d = 507.00$$

$$d' = 43.00$$

$$v = 0.0032437$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01464812$$

$$\phi_{cc} \text{ ((5.4c), TBDY) } = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07767542$$

where $\phi_f = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$\phi_{fy} = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00406911$$

$$\text{psh}_x \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 1760.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 262500.00$$

$$\text{psh}_y \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 1360.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

s = 100.00
fywe = 656.25
fce = 24.00

From ((5.A.5), TBDY), TBDY: cc = 0.0050771
c = confinement factor = 1.30771

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.48796927

2 = Asl,com/(b*d)*(fs2/fc) = 0.17892207

v = Asl,mid/(b*d)*(fsv/fc) = 0.44459423

and confined core properties:

b = 190.00
d = 477.00
d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.68244627$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.2502303$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.62178438$$

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 not satisfied

---->
Case/Assumption Rejected.

---->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)

---->
 $v < v_{s,y1}$ - LHS eq.(4.7) is not satisfied

---->
 $v < v_{c,y1}$ - RHS eq.(4.6) is satisfied

---->
 ϵ_{cu} (4.10) = 0.43574957

MRc (4.17) = 8.0482E+008

---->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
- N_1, N_2, v normalised to b_o*d_o , instead of $b*d$
- parameters of confined concrete, f_{cc}, ϵ_{cc} , used in lieu of f_c, ϵ_{cu}

---->
Subcase: Rupture of tension steel

---->
 $v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->
 $v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->
Subcase rejected

---->
New Subcase: Failure of compression zone

---->
 $v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->
 $v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied

---->
 ϵ^*_{cu} (4.10) = 0.5092345

MRO (4.17) = 9.6827E+008

---->
 $u = \epsilon^*_{cu}$ (4.2) = 2.0901588E-005
 $M_u = M_{RO}$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of M_{u2}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 7.5354574E-005$
 $M_u = 8.4161E+008$

with full section properties:
 $b = 750.00$
 $d = 507.00$
 $d' = 43.00$

$$v = 0.00108123$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01464812$$

$$\text{we (5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.35771528$$

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.

$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1760.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 262500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1360.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$f_{y1} = 656.25$
 $s_{u1} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{u1} = 0.4 * e_{su1,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{su1,nominal} = 0.08$,
 For calculation of $e_{su1,nominal}$ and y_1, sh_1, ft_1, f_{y1} , it is considered
 characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s1} = f_s = 656.25$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $f_{y2} = 656.25$
 $s_{u2} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$
 $s_{u2} = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,
 For calculation of $e_{su2,nominal}$ and y_2, sh_2, ft_2, f_{y2} , it is considered
 characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_2, sh_2, ft_2, f_{y2} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 656.25$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $f_{y_v} = 656.25$
 $s_{u_v} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{u_v} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,
 considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, f_{y_v} , it is considered
 characteristic value $f_{sv} = f_{sv}/1.2$, 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 $f_{sv} = f_s = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05964069$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.16265642$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.14819808$
 and confined core properties:
 $b = 690.00$
 $d = 477.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.068904$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.18791999$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.17121599$
 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
 --->
 $s_u (4.8) = 0.16240824$

$$\begin{aligned} \mu &= MRC(4.15) = 8.4161E+008 \\ u &= su(4.1) = 7.5354574E-005 \end{aligned}$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 426086.999$

Calculation of Shear Strength at edge 1, $V_{r1} = 426086.999$

$$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$$

$$V_{Col0} = 426086.999$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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 (normal-weight concrete)

$$f_c' = 24.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$\mu = 867.1065$$

$$V_u = 0.00020794$$

$$d = 0.8 * h = 440.00$$

$$N_u = 9867.325$$

$$A_g = 137500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 527787.566$$

where:

$V_{s1} = 362853.951$ is calculated for section web, with:

$$d = 440.00$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

V_{s1} is multiplied by $Col1 = 1.00$

$$s/d = 0.22727273$$

$V_{s2} = 164933.614$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

V_{s2} is multiplied by $Col2 = 1.00$

$$s/d = 0.50$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 267149.446$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = b1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 507.00$$

$$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 357985.191$$

$$b_w = 250.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 426086.999$

$$V_{r2} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$$

$$V_{Col0} = 426086.999$$

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' = 24.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 867.1065

Vu = 0.00020794

d = 0.8*h = 440.00

Nu = 9867.325

Ag = 137500.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 527787.566

where:

Vs1 = 362853.951 is calculated for section web, with:

d = 440.00

Av = 157079.633

fy = 525.00

s = 100.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.22727273

Vs2 = 164933.614 is calculated for section flange, with:

d = 200.00

Av = 157079.633

fy = 525.00

s = 100.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.50

Vf ((11-3)-(11.4), ACI 440) = 267149.446

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(θ), is implemented for every different fiber orientation ai,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, θ)|, |Vf(-45, θ)|), with:

total thickness per orientation, tf1 = NL*t/NoDir = 1.016

dfv = d (figure 11.2, ACI 440) = 507.00

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 <= 357985.191

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\phi = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, fc = fcm = 24.00

Existing material of Primary Member: Steel Strength, fs = fsm = 525.00

Concrete Elasticity, Ec = 23025.204

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, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $Ecc = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.30771

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou,min} > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = 5.0286180E-008$

EDGE -B-

Shear Force, $V_b = -5.0286180E-008$

BOTH EDGES

Axial Force, $F = -9867.325$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{,ten} = 1231.504$

-Compression: $As_{,com} = 1231.504$

-Middle: $As_{,mid} = 2689.203$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.21891$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 820555.407$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.2308E+009$

$Mu_{1+} = 1.2308E+009$, 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

$Mu_{1-} = 1.2308E+009$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.2308E+009$

$Mu_{2+} = 1.2308E+009$, 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

$Mu_{2-} = 1.2308E+009$, 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 Mu1+

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 7.4763506E-005$$

$$Mu = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01464812$$

$$w_e \text{ ((5.4c), TBDY)} = a_s e * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1760.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 262500.00$$

$$\text{psh,y ((5.4d), TBDY)} = \text{Lstir} \cdot \text{Astir} / (\text{Asec} \cdot \text{s}) = 0.00526591$$

$$\text{Lstir (Length of stirrups along X)} = 1360.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 262500.00$$

$$\text{s} = 100.00$$

$$\text{fywe} = 656.25$$

$$\text{fce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: cc} = 0.0050771$$

$$\text{c} = \text{confinement factor} = 1.30771$$

$$\text{y1} = 0.0025$$

$$\text{sh1} = 0.008$$

$$\text{ft1} = 787.50$$

$$\text{fy1} = 656.25$$

$$\text{su1} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/ld} = 1.00$$

$$\text{su1} = 0.4 \cdot \text{esu1_nominal} ((5.5), \text{TBDY}) = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fs1} = \text{fs} = 656.25$$

$$\text{with Es1} = \text{Es} = 200000.00$$

$$\text{y2} = 0.0025$$

$$\text{sh2} = 0.008$$

$$\text{ft2} = 787.50$$

$$\text{fy2} = 656.25$$

$$\text{su2} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/lb,min} = 1.00$$

$$\text{su2} = 0.4 \cdot \text{esu2_nominal} ((5.5), \text{TBDY}) = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fs2} = \text{fs} = 656.25$$

$$\text{with Es2} = \text{Es} = 200000.00$$

$$\text{yv} = 0.0025$$

$$\text{shv} = 0.008$$

$$\text{ftv} = 787.50$$

$$\text{fyv} = 656.25$$

$$\text{su} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/ld} = 1.00$$

$$\text{su} = 0.4 \cdot \text{esuv_nominal} ((5.5), \text{TBDY}) = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (\text{lb/ld})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fsv} = \text{fs} = 656.25$$

$$\text{with Esv} = \text{Es} = 200000.00$$

$$1 = \text{Asl,ten} / (\text{b} \cdot \text{d}) \cdot (\text{fs1} / \text{fc}) = 0.19051738$$

$$2 = \text{Asl,com} / (\text{b} \cdot \text{d}) \cdot (\text{fs2} / \text{fc}) = 0.19051738$$

$$\text{v} = \text{Asl,mid} / (\text{b} \cdot \text{d}) \cdot (\text{fsv} / \text{fc}) = 0.41602774$$

and confined core properties:

$$\text{b} = 190.00$$

$$\text{d} = 677.00$$

$$\text{d}' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 31.38503$$

$$c_c (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$$

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

---->

$$s_u (4.8) = 0.39460211$$

$$\mu_u = M_{Rc} (4.15) = 1.2308E+009$$

$$u = s_u (4.1) = 7.4763506E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 7.4763506E-005$$

$$\mu_u = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01464812$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.35771528$

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.

$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

$s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

c = confinement factor = 1.30771

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_1 = 0.4 \cdot esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 \cdot esu2_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_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 $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$f_{tv} = 787.50$
 $f_{yv} = 656.25$
 $s_{uv} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,
 considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $e_{suv_nominal}$ and γ_v , sh_v, f_{tv}, f_{yv} , it is considered
 characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.
 $\gamma_1, sh_1, f_{t1}, f_{y1}$, are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19051738$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.19051738$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.41602774$
 and confined core properties:
 $b = 190.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.26178921$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.26178921$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.57166216$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 7.4763506E-005$

$\mu_{\mu} = 1.2308E+009$

with full section properties:

$b = 250.00$

$d = 707.00$

$d' = 43.00$

$v = 0.0023261$

$N = 9867.325$

$f_c = 24.00$

$c_o (5A.5, TBDY) = 0.002$

Final value of μ_c : $\mu_c^* = shear_factor * Max(\mu_c, c_o) = 0.01464812$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.01464812$

$w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + Min(f_x, f_y) = 0.07767542$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 748.2496$

$$f_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$$b_w = 250.00$$

effective stress from (A.35), $f_{f,e} = 748.2496$

$$R = 40.00$$

Effective FRP thickness, $t_f = N_L * t * \cos(b_1) = 1.016$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$$

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1760.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 262500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1360.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 24.00$$

From ((5.A5), TBDY), TBDY: $c_c = 0.0050771$

$$c = \text{confinement factor} = 1.30771$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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 $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s1} = f_s = 656.25$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered

characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s2} = f_s = 656.25$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_v = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

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.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.19051738$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.19051738$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.41602774$

and confined core properties:

$b = 190.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 31.38503$

$cc (5A.5, TBDY) = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.26178921$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.26178921$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.57166216$

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

---->

$su (4.8) = 0.39460211$

$M_u = MR_c (4.15) = 1.2308E+009$

$u = su (4.1) = 7.4763506E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu2-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 7.4763506E-005$$

$$Mu = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$co (5A.5, TBDY) = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.01464812$$

$$we ((5.4c), TBDY) = ase * sh_{,min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.07767542$$

where $f = af * pf * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff_e = 748.2496$$

$$fy = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff_e = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL * t * \text{Cos}(b1) = 1.016$$

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.35771528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).

$$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00406911$$

$$psh_x ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$$

$$L_{stir} (\text{Length of stirrups along } Y) = 1760.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 262500.00$$

$$\text{psh,y ((5.4d), TBDY)} = \text{Lstir} \cdot \text{Astir} / (\text{Asec} \cdot \text{s}) = 0.00526591$$

$$\text{Lstir (Length of stirrups along X)} = 1360.00$$

$$\text{Astir (stirrups area)} = 78.53982$$

$$\text{Asec (section area)} = 262500.00$$

 $s = 100.00$

$$\text{fywe} = 656.25$$

$$\text{fce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$\text{sh1} = 0.008$$

$$\text{ft1} = 787.50$$

$$\text{fy1} = 656.25$$

$$\text{su1} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/l d} = 1.00$$

$$\text{su1} = 0.4 \cdot \text{esu1_nominal ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (\text{lb/l d})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fs1} = \text{fs} = 656.25$$

$$\text{with Es1} = \text{Es} = 200000.00$$

$$y2 = 0.0025$$

$$\text{sh2} = 0.008$$

$$\text{ft2} = 787.50$$

$$\text{fy2} = 656.25$$

$$\text{su2} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/l b,min} = 1.00$$

$$\text{su2} = 0.4 \cdot \text{esu2_nominal ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (\text{lb/l d})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fs2} = \text{fs} = 656.25$$

$$\text{with Es2} = \text{Es} = 200000.00$$

$$yv = 0.0025$$

$$\text{shv} = 0.008$$

$$\text{ftv} = 787.50$$

$$\text{fyv} = 656.25$$

$$\text{su v} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/l d} = 1.00$$

$$\text{su v} = 0.4 \cdot \text{esuv_nominal ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (\text{lb/l d})^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with fsv} = \text{fs} = 656.25$$

$$\text{with Esv} = \text{Es} = 200000.00$$

$$1 = \text{Asl,ten} / (\text{b} \cdot \text{d}) \cdot (\text{fs1} / \text{fc}) = 0.19051738$$

$$2 = \text{Asl,com} / (\text{b} \cdot \text{d}) \cdot (\text{fs2} / \text{fc}) = 0.19051738$$

$$v = \text{Asl,mid} / (\text{b} \cdot \text{d}) \cdot (\text{fsv} / \text{fc}) = 0.41602774$$

and confined core properties:

$$b = 190.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$\text{fcc (5A.2, TBDY)} = 31.38503$$

$$cc(5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.26178921$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.26178921$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.57166216$$

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

---->

$$su(4.8) = 0.39460211$$

$$Mu = MRc(4.15) = 1.2308E+009$$

$$u = su(4.1) = 7.4763506E-005$$

Calculation of ratio lb/d

Adequate Lap Length: $lb/d \geq 1$

Calculation of Shear Strength $Vr = \text{Min}(Vr1, Vr2) = 673185.175$

Calculation of Shear Strength at edge 1, $Vr1 = 673185.175$

$$Vr1 = VCol((10.3), ASCE 41-17) = knl * VCol0$$

$$VCol0 = 673185.175$$

$$knl = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$$fc' = 24.00, \text{ but } fc'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$Mu = 0.48500011$$

$$Vu = 5.0286180E-008$$

$$d = 0.8 * h = 600.00$$

$$Nu = 9867.325$$

$$Ag = 187500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } Vs = Vs1 + Vs2 = 659734.457$$

where:

$Vs1 = 164933.614$ is calculated for section web, with:

$$d = 200.00$$

$$Av = 157079.633$$

$$fy = 525.00$$

$$s = 100.00$$

$Vs1$ is multiplied by $Col1 = 1.00$

$$s/d = 0.50$$

$Vs2 = 494800.843$ is calculated for section flange, with:

$$d = 600.00$$

$$Av = 157079.633$$

$$fy = 525.00$$

$$s = 100.00$$

$Vs2$ is multiplied by $Col2 = 1.00$

$$s/d = 0.16666667$$

$$Vf((11-3)-(11.4), ACI 440) = 372533.843$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc)\sin\alpha$ which is more a generalised expression,
where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $Vf(\alpha)$, is implemented for every different fiber orientation α_i ,
as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = 90^\circ = 90.00$

$$Vf = \text{Min}(|Vf(45, 1)|, |Vf(-45, \alpha_1)|), \text{ with:}$$

total thickness per orientation, $tf1 = NL*t/NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 707.00
 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: $Vs + Vf \leq 488161.625$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $Vr2 = 673185.175$
 $Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl*VColO$
 $VColO = 673185.175$
 $knl = 1$ (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)
 $fc' = 24.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $Mu = 0.48484922$
 $Vu = 5.0286180E-008$
 $d = 0.8*h = 600.00$
 $Nu = 9867.325$
 $Ag = 187500.00$
From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 659734.457$
where:

$Vs1 = 164933.614$ is calculated for section web, with:
 $d = 200.00$
 $Av = 157079.633$
 $fy = 525.00$
 $s = 100.00$

$Vs1$ is multiplied by $Col1 = 1.00$
 $s/d = 0.50$

$Vs2 = 494800.843$ is calculated for section flange, with:
 $d = 600.00$
 $Av = 157079.633$
 $fy = 525.00$
 $s = 100.00$

$Vs2$ is multiplied by $Col2 = 1.00$
 $s/d = 0.16666667$

Vf ((11-3)-(11.4), ACI 440) = 372533.843
 $f = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot\alpha)\sin\alpha$ which is more a generalised expression,
where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $Vf(\alpha)$, 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: $\alpha = 45^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, \alpha)|, |Vf(-45, \alpha)|)$, with:

total thickness per orientation, $tf1 = NL*t/NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 707.00
 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: $Vs + Vf \leq 488161.625$
 $bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $Ecc = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/l_d >= 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -7.7550E+006$

Shear Force, $V_2 = -2555.206$

Shear Force, $V_3 = 59.77842$

Axial Force, $F = -10159.171$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1231.504$

-Compression: $As_{c,com} = 1231.504$

-Middle: $As_{mid} = 2689.203$

Mean Diameter of Tension Reinforcement, $Db_L = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \gamma * u = 0.0499861$

$u = \gamma + p = 0.0499861$

- Calculation of γ -

$\gamma = (My * Ls / 3) / Eleff = 0.01046826 ((4.29), Biskinis Phd)$

$My = 6.5614E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3034.966
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 6.3409E+013$
 factor = 0.30
 $A_g = 262500.00$
 $f_c' = 24.00$
 $N = 10159.171$
 $E_c \cdot I_g = 2.1136E+014$

 Calculation of Yielding Moment M_y

 Calculation of ρ_y and M_y according to Annex 7 -

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 5.4982839E-006$
 with $f_y = 525.00$
 $d = 707.00$
 $y = 0.3247218$
 $A = 0.0292592$
 $B = 0.01557079$
 with $p_t = 0.00696749$
 $p_c = 0.00696749$
 $p_v = 0.01521473$
 $N = 10159.171$
 $b = 250.00$
 $\rho = 0.06082037$
 $y_{comp} = 8.2388357E-006$
 with f_c^* (12.3, (ACI 440)) = 24.16756
 $f_c = 24.00$
 $f_l = 0.56655003$
 $b = b_{max} = 750.00$
 $h = h_{max} = 550.00$
 $A_g = 262500.00$
 $g = p_t + p_c + p_v = 0.02914971$
 $rc = 40.00$
 $A_e/A_c = 0.17542991$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 23025.204$
 $y = 0.32435206$
 $A = 0.0289976$
 $B = 0.01546131$
 with $E_s = 200000.00$

 Calculation of ratio I_b/I_d

 Adequate Lap Length: $I_b/I_d \geq 1$

 - Calculation of ρ_p -

 From table 10-8: $\rho_p = 0.03951783$

with:

- Columns controlled by inadequate development or splicing along the clear height because $I_b/I_d < 1$

shear control ratio $V_y E / V C o l O E = 1.21891$

$d = 707.00$

$s = 0.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = A_v \cdot L_{stir} / (A_g \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1760.00$, 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 = 10159.171
Ag = 262500.00
fcE = 24.00
fytE = fylE = 0.00
pl = Area_Tot_Long_Rein/(b*d) = 0.02914971
b = 250.00
d = 707.00
fcE = 24.00

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1
At local axis: 3
Integration Section: (a)

Calculation No. 13

column C1, Floor 1
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Shear capacity VRd
Edge: End
Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1
At local axis: 2
Integration Section: (b)
Section Type: rctcs

Constant Properties

Knowledge Factor, = 1.00
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Primary Member: Concrete Strength, fc = fc_lower_bound = 16.00
Existing material of Primary Member: Steel Strength, fs = fs_lower_bound = 420.00

Concrete Elasticity, $E_c = 23025.204$

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, $f_c = f_{cm} = 24.00$

Existing material: Steel Strength, $f_s = f_{sm} = 525.00$

#####

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $E_{cc} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{o,min} = l_b/l_d \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -7.7550E+006$

Shear Force, $V_a = -2555.206$

EDGE -B-

Bending Moment, $M_b = 87395.69$

Shear Force, $V_b = 2555.206$

BOTH EDGES

Axial Force, $F = -10159.171$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1231.504$

-Compression: $A_{sl,com} = 1231.504$

-Middle: $A_{sl,mid} = 2689.203$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 550068.868$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 550068.868$

$V_{CoI} = 550068.868$

$k_n = 1.00$

$\text{displacement_ductility_demand} = 0.01809475$

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + \phi V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 87395.69$

$V_u = 2555.206$

$d = 0.8 \cdot h = 600.00$

$N_u = 10159.171$

$A_g = 187500.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 527787.566$

where:

$V_{s1} = 131946.891$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 420.00$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.50$

$V_{s2} = 395840.674$ is calculated for section flange, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 420.00$

$s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.16666667$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, 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, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 398582.298$

$b_w = 250.00$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END B -

for rotation axis 3 and integ. section (b)

From analysis, chord rotation $\theta = 1.8723826E-005$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00103477$ ((4.29), Biskinis Phd)

$M_y = 6.5614E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 6.3409E+013$

factor = 0.30

$A_g = 262500.00$

$f_c' = 24.00$

$N = 10159.171$

$E_c \cdot I_g = 2.1136E+014$

Calculation of Yielding Moment M_y

Calculation of δ and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 5.4982839E-006$

with $f_y = 525.00$
 $d = 707.00$
 $y = 0.3247218$
 $A = 0.0292592$
 $B = 0.01557079$
with $pt = 0.00696749$
 $pc = 0.00696749$
 $pv = 0.01521473$
 $N = 10159.171$
 $b = 250.00$
 $" = 0.06082037$
 $y_{comp} = 8.2388357E-006$
with $fc^* (12.3, (ACI 440)) = 24.16756$
 $fc = 24.00$
 $fl = 0.56655003$
 $b = b_{max} = 750.00$
 $h = h_{max} = 550.00$
 $Ag = 262500.00$
 $g = pt + pc + pv = 0.02914971$
 $rc = 40.00$
 $Ae/Ac = 0.17542991$
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), $efe = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 23025.204$
 $y = 0.32435206$
 $A = 0.0289976$
 $B = 0.01546131$
with $Es = 200000.00$

Calculation of ratio lb/d

Adequate Lap Length: $lb/d \geq 1$

End Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 14

column C1, Floor 1

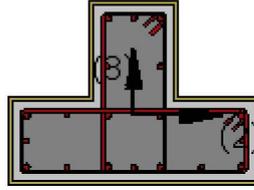
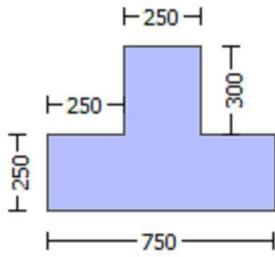
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rctcs

Constant Properties

Knowledge Factor, $= 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

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, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $Ecc = 250.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.30771

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou}, \min > = 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.00020794$

EDGE -B-

Shear Force, $V_b = -0.00020794$
BOTH EDGES
Axial Force, $F = -9867.325$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 2261.947$
-Compression: $A_{sc,com} = 829.3805$
-Middle: $A_{sc,mid} = 2060.885$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.51499$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 645516.591$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 9.6827E+008$
 $M_{u1+} = 9.6827E+008$, 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
 $M_{u1-} = 8.4161E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 9.6827E+008$
 $M_{u2+} = 9.6827E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $M_{u2-} = 8.4161E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 2.0901588E-005$
 $M_u = 9.6827E+008$

with full section properties:

$b = 250.00$
 $d = 507.00$
 $d' = 43.00$
 $v = 0.0032437$
 $N = 9867.325$

$f_c = 24.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01464812$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_{cu} = 0.01464812$

where ϕ_{cu} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07767542$

where $\phi_{fx} = \alpha_{f} * \text{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_{fx} = 0.03787432$

Expression ((15B.6), TBDY) is modified as $\alpha_{f} = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_{f} = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$

$b_{max} = 750.00$

$h_{max} = 550.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 748.2496$

 $\phi_{fy} = 0.03787432$

Expression ((15B.6), TBDY) is modified as $\alpha_{f} = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_{f} = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 750.00$

hmax = 550.00
From EC8 A.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 748.2496$

R = 40.00
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$
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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$
 L_{stir} (Length of stirrups along Y) = 1760.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 262500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$
 L_{stir} (Length of stirrups along X) = 1360.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 262500.00

s = 100.00
 $f_{ywe} = 656.25$
 $f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$
c = confinement factor = 1.30771

$y1 = 0.0025$
 $sh1 = 0.008$
 $ft1 = 787.50$
 $fy1 = 656.25$
 $su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 656.25$

with $Es1 = Es = 200000.00$

$y2 = 0.0025$
 $sh2 = 0.008$
 $ft2 = 787.50$
 $fy2 = 656.25$
 $su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su2 = 0.4 * esu2_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and $y2, sh2, ft2, fy2$, it is considered

characteristic value $f_{s2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $f_{s2} = f_s = 656.25$
with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $f_{y_v} = 656.25$
 $s_{u_v} = 0.032$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $s_{u_v} = 0.4 \cdot e_{s_{u_v,nominal}} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $e_{s_{u_v,nominal}} = 0.08$,
considering characteristic value $f_{s_{y_v}} = f_{s_{y_v}}/1.2$, from table 5.1, TBDY
For calculation of $e_{s_{u_v,nominal}}$ and y_v, sh_v, ft_v, f_{y_v} , it is considered
characteristic value $f_{s_{y_v}} = f_{s_{y_v}}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $f_{s_v} = f_s = 656.25$
with $E_{s_v} = E_s = 200000.00$
 $1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.48796927$
 $2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.17892207$
 $v = A_{s1,mid}/(b \cdot d) \cdot (f_{s_v}/f_c) = 0.44459423$
and confined core properties:
 $b = 190.00$
 $d = 477.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.68244627$
 $2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.2502303$
 $v = A_{s1,mid}/(b \cdot d) \cdot (f_{s_v}/f_c) = 0.62178438$
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 not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
 $v < s_{y1}$ - LHS eq.(4.7) is not satisfied
--->
 $v < v_{c,y1}$ - RHS eq.(4.6) is satisfied
--->
 $c_u (4.10) = 0.43574957$
 $M_{Rc} (4.17) = 8.0482E+008$
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
- $N, 1, 2, v$ normalised to $b_o \cdot d_o$, instead of $b \cdot d$
- f_{cc}, cc parameters of confined concrete, f_{cc}, cc , used in lieu of f_c, e_{cu}
--->
Subcase: Rupture of tension steel
--->
 $v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied
--->
 $v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied
--->
Subcase rejected
--->

New Subcase: Failure of compression zone

--->

$v^* < v^*c,y2$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^*c,y1$ - RHS eq.(4.6) is satisfied

--->

*cu (4.10) = 0.5092345

M_{Ro} (4.17) = 9.6827E+008

--->

u = cu (4.2) = 2.0901588E-005

Mu = M_{Ro}

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 7.5354574E-005

Mu = 8.4161E+008

with full section properties:

b = 750.00

d = 507.00

d' = 43.00

v = 0.00108123

N = 9867.325

f_c = 24.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01464812

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01464812

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.07767542

where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.03787432

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.14946032

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 39233.333

bmax = 750.00

hmax = 550.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128

bw = 250.00

effective stress from (A.35), ff,e = 748.2496

fy = 0.03787432

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.14946032

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 0.00

bmax = 750.00

hmax = 550.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128

bw = 250.00

effective stress from (A.35), ff,e = 748.2496

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-A_{noConf})/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.35771528

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.

$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with $\text{Shear_factor} = 1.00$

$lo/lo_{u,min} = lb/ld = 1.00$

$su_1 = 0.4 * esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with $\text{Shear_factor} = 1.00$

$lo/lo_{u,min} = lb/lb_{,min} = 1.00$

$su_2 = 0.4 * esu_{2,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.05964069

2 = Asl,com/(b*d)*(fs2/fc) = 0.16265642

v = Asl,mid/(b*d)*(fsv/fc) = 0.14819808

and confined core properties:

b = 690.00

d = 477.00

d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

1 = Asl,ten/(b*d)*(fs1/fc) = 0.068904

2 = Asl,com/(b*d)*(fs2/fc) = 0.18791999

v = Asl,mid/(b*d)*(fsv/fc) = 0.17121599

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) = 0.16240824

Mu = MRc (4.15) = 8.4161E+008

u = su (4.1) = 7.5354574E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 2.0901588E-005

Mu = 9.6827E+008

with full section properties:

b = 250.00

d = 507.00

d' = 43.00

v = 0.0032437

N = 9867.325

fc = 24.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01464812

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01464812

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.07767542

where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.03787432

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.14946032

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 39233.333

bmax = 750.00
hmax = 550.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 748.2496$

fy = 0.03787432
Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$
af = 0.14946032
with Unconfined area = $((bmax-2R)^2 + (hmax-2R)^2)/3 = 0.00$
bmax = 750.00
hmax = 550.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 748.2496$

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 = $Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.35771528$
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 = 188100.00 is the confined core 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 = 137025.00 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 = 95733.333 is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).
 $psh,min = Min(psh,x, psh,y) = 0.00406911$

psh,x ((5.4d), TBDY) = $Lstir*Astir/(Asec*s) = 0.00406911$
Lstir (Length of stirrups along Y) = 1760.00
Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

psh,y ((5.4d), TBDY) = $Lstir*Astir/(Asec*s) = 0.00526591$
Lstir (Length of stirrups along X) = 1360.00
Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

s = 100.00
fywe = 656.25
fce = 24.00
From ((5.A5), TBDY), TBDY: $cc = 0.0050771$
c = confinement factor = 1.30771
y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou,min = lb/d = 1.00$
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 $fs1 = fs = 656.25$
with $Es1 = Es = 200000.00$
y2 = 0.0025

```

sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032
  using (30) in Biskinis/Fardis (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 = 1.00
  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 = 656.25
  with Es2 = Es = 200000.00
yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032
  using (30) in Biskinis/Fardis (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 = 1.00
  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 = 656.25
  with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.48796927
2 = Asl,com/(b*d)*(fs2/fc) = 0.17892207
v = Asl,mid/(b*d)*(fsv/fc) = 0.44459423
and confined core properties:
b = 190.00
d = 477.00
d' = 13.00
fcc (5A.2, TBDY) = 31.38503
cc (5A.5, TBDY) = 0.0050771
c = confinement factor = 1.30771
1 = Asl,ten/(b*d)*(fs1/fc) = 0.68244627
2 = Asl,com/(b*d)*(fs2/fc) = 0.2502303
v = Asl,mid/(b*d)*(fsv/fc) = 0.62178438
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 not satisfied
--->
Case/Assumption Rejected.
--->
New Case/Assumption: Unconfined full section - Spalling of concrete cover
' satisfies Eq. (4.4)
--->
v < s,y1 - LHS eq.(4.7) is not satisfied
--->
v < vc,y1 - RHS eq.(4.6) is satisfied
--->
cu (4.10) = 0.43574957
MRc (4.17) = 8.0482E+008
--->
New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
In expressions below, the following modifications have been made
- b, d, d' replaced by geometric parameters of the core: bo, do, d'o

```

- N, 1, 2, v normalised to $b_0 \cdot d_0$, instead of $b \cdot d$
- parameters of confined concrete, f_{cc} , c_c , used in lieu of f_c , e_{cu}

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

* c_u (4.10) = 0.5092345

M R_o (4.17) = 9.6827E+008

---->

$u = c_u$ (4.2) = 2.0901588E-005

$\mu_u = M R_o$

 Calculation of ratio l_b/l_d

 Adequate Lap Length: $l_b/l_d \geq 1$

 Calculation of μ_{u2}

 Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$u = 7.5354574E-005$

$\mu_u = 8.4161E+008$

 with full section properties:

$b = 750.00$

$d = 507.00$

$d' = 43.00$

$v = 0.00108123$

$N = 9867.325$

$f_c = 24.00$

c_o (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} \cdot \text{Max}(c_u, c_c) = 0.01464812$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01464812$

w_e ((5.4c), TBDY) = $a_s e \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$

where $f = a_f \cdot p_f \cdot f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.03787432$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.14946032$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$

$b_{\max} = 750.00$

$h_{\max} = 550.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 748.2496$

 $f_y = 0.03787432$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.14946032$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

$b_{\max} = 750.00$

hmax = 550.00
From EC8 A.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 748.2496$

R = 40.00
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$
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.
 $A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.
 $A_{\text{conf,min}} = 137025.00$ 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.
 $A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$
 L_{stir} (Length of stirrups along Y) = 1760.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 262500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$
 L_{stir} (Length of stirrups along X) = 1360.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 262500.00

s = 100.00
 $f_{ywe} = 656.25$
 $f_{ce} = 24.00$
From ((5.A5), TBDY), TBDY: $cc = 0.0050771$
c = confinement factor = 1.30771

$y1 = 0.0025$
 $sh1 = 0.008$
 $ft1 = 787.50$
 $fy1 = 656.25$
 $su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 656.25$

with $Es1 = Es = 200000.00$

$y2 = 0.0025$
 $sh2 = 0.008$
 $ft2 = 787.50$
 $fy2 = 656.25$
 $su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su2 = 0.4 * esu2_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and $y2, sh2, ft2, fy2$, it is considered

characteristic value $f_{s2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s2} = f_s = 656.25$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$f_{y_v} = 656.25$

$s_{u_v} = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/d = 1.00$

$s_{u_v} = 0.4 \cdot e_{s_{u_v,nominal}} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{s_{u_v,nominal}} = 0.08$,

considering characteristic value $f_{s_{y_v}} = f_{s_{y_v}}/1.2$, from table 5.1, TBDY

For calculation of $e_{s_{u_v,nominal}}$ and y_v, sh_v, ft_v, f_{y_v} , it is considered
characteristic value $f_{s_{y_v}} = f_{s_{y_v}}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s_{y_v}} = f_s = 656.25$

with $E_{s_{y_v}} = E_s = 200000.00$

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.05964069$

2 = $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16265642$

v = $A_{s1,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.14819808$

and confined core properties:

$b = 690.00$

$d = 477.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 31.38503$

$cc (5A.5, TBDY) = 0.0050771$

c = confinement factor = 1.30771

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.068904$

2 = $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.18791999$

v = $A_{s1,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.17121599$

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

--->

$s_u (4.8) = 0.16240824$

$\mu_u = M_{Rc} (4.15) = 8.4161E+008$

u = $s_u (4.1) = 7.5354574E-005$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 426086.999$

Calculation of Shear Strength at edge 1, $V_{r1} = 426086.999$

$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Co10}$

$V_{Co10} = 426086.999$

$k_{nl} = 1$ (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)

$f_c' = 24.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 867.1065$

$V_u = 0.00020794$
 $d = 0.8 \cdot h = 440.00$
 $N_u = 9867.325$
 $A_g = 137500.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 527787.566$
 where:
 $V_{s1} = 362853.951$ is calculated for section web, with:
 $d = 440.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.22727273$
 $V_{s2} = 164933.614$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 V_f ((11-3)-(11.4), ACI 440) = 267149.446
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, 1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 507.00
 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: $V_s + V_f \leq 357985.191$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 426086.999$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 426086.999$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'V_s' is replaced by 'V_s + f * V_f'
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 24.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 867.1065$
 $V_u = 0.00020794$
 $d = 0.8 \cdot h = 440.00$
 $N_u = 9867.325$
 $A_g = 137500.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 527787.566$
 where:
 $V_{s1} = 362853.951$ is calculated for section web, with:
 $d = 440.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.22727273$
 $V_{s2} = 164933.614$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$

$f_y = 525.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 $V_f((11-3)-(11.4), ACI 440) = 267149.446$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 507.00
 $f_{fe}((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 357985.191$
 $bw = 250.00$

 End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rctcs

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 23025.204$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 656.25$
 #####
 Max Height, $H_{max} = 550.00$
 Min Height, $H_{min} = 250.00$
 Max Width, $W_{max} = 750.00$
 Min Width, $W_{min} = 250.00$
 Eccentricity, $Ecc = 250.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.30771
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_o / l_{ou, min} > 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 5.0286180E-008$
EDGE -B-
Shear Force, $V_b = -5.0286180E-008$
BOTH EDGES
Axial Force, $F = -9867.325$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1231.504$
-Compression: $As_{l,com} = 1231.504$
-Middle: $As_{l,mid} = 2689.203$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.21891$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 820555.407$
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.2308E+009$
 $\mu_{1+} = 1.2308E+009$, 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
 $\mu_{1-} = 1.2308E+009$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.2308E+009$
 $\mu_{2+} = 1.2308E+009$, 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
 $\mu_{2-} = 1.2308E+009$, 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_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 7.4763506E-005$
 $\mu_u = 1.2308E+009$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.01464812$$

$$\mu_u \text{ ((5.4c), TBDY)} = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

where $f = a_f * \rho_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$

$b_{max} = 750.00$

$h_{max} = 550.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff,e = 748.2496$

$fy = 0.03787432$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 750.00$

$h_{max} = 550.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff,e = 748.2496$

$R = 40.00$

Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$

$fu,f = 1055.00$

$Ef = 64828.00$

$u,f = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.35771528$

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.

$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $bi^2/6$ as defined at (A.2).
 $psh,min = \text{Min}(psh,x, psh,y) = 0.00406911$

psh,x ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

psh,y ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

$s = 100.00$

$fywe = 656.25$

$fce = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 787.50$

$fy1 = 656.25$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/d = 1.00$

$su1 = 0.4*esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s1} = f_s = 656.25$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 656.25$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.19051738$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.19051738$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.41602774$
 and confined core properties:
 $b = 190.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$
 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
 --->
 $su (4.8) = 0.39460211$
 $Mu = MR_c (4.15) = 1.2308E+009$
 $u = su (4.1) = 7.4763506E-005$

 Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 7.4763506E-005$$

$$\mu_u = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u = \text{shear_factor} * \text{Max}(\mu_c, \mu_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.01464812$$

$$\mu_{ue} ((5.4c), \text{TBDY}) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.07767542$$

where $\mu_x = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 748.2496$$

$$\mu_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$\mu_{sh,\min} = \text{Min}(\mu_{sh,x}, \mu_{sh,y}) = 0.00406911$$

$$\mu_{sh,x} ((5.4d), \text{TBDY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} (\text{Length of stirrups along Y}) = 1760.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 262500.00$$

$$\mu_{sh,y} ((5.4d), \text{TBDY}) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} (\text{Length of stirrups along X}) = 1360.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

s = 100.00
fywe = 656.25
fce = 24.00

From ((5.A.5), TBDY), TBDY: cc = 0.0050771
c = confinement factor = 1.30771

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19051738

2 = Asl,com/(b*d)*(fs2/fc) = 0.19051738

v = Asl,mid/(b*d)*(fsv/fc) = 0.41602774

and confined core properties:

b = 190.00
d = 677.00
d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$$

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

--->

$$s_u(4.8) = 0.39460211$$

$$\mu_u = M_{Rc}(4.15) = 1.2308E+009$$

$$u = s_u(4.1) = 7.4763506E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{u2+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 7.4763506E-005$$

$$\mu_u = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01464812$$

$$w_e(5.4c, TBDY) = a_s * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

u,f = 0.015

ase = Max(((Aconf,max-AnoConf)/Aconf,max)*(Aconf,min/Aconf,max),0) = 0.35771528

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 = 188100.00 is the confined core 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 = 137025.00 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 = 95733.333 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) = 0.00406911

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00406911

Lstir (Length of stirrups along Y) = 1760.00

Astir (stirrups area) = 78.53982

Asec (section area) = 262500.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00526591

Lstir (Length of stirrups along X) = 1360.00

Astir (stirrups area) = 78.53982

Asec (section area) = 262500.00

s = 100.00

fywe = 656.25

fce = 24.00

From ((5.A5), TBDY), TBDY: cc = 0.0050771

c = confinement factor = 1.30771

y1 = 0.0025

sh1 = 0.008

ft1 = 787.50

fy1 = 656.25

su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/l_d = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/l_d)^2/3), from 10.3.5, ASCE41-17.

with fs1 = fs = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 787.50

fy2 = 656.25

su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/l_b,min = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/l_d)^2/3), from 10.3.5, ASCE41-17.

with fs2 = fs = 656.25

with Es2 = Es = 200000.00

yv = 0.0025

shv = 0.008

ftv = 787.50

fyv = 656.25

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_0/l_{0,min} = l_b/l_d = 1.00$

$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv,nominal}$ and γ_v , sh_v, f_{tv}, f_{yv} , it is considered
characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_1 , sh_1, f_{t1}, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19051738$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.19051738$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.41602774$

and confined core properties:

$b = 190.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 31.38503$

$cc (5A.5, TBDY) = 0.0050771$

$c =$ confinement factor = 1.30771

$1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.26178921$

$2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.26178921$

$v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.57166216$

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

$s_u (4.8) = 0.39460211$

$M_u = M_{Rc} (4.15) = 1.2308E+009$

$u = s_u (4.1) = 7.4763506E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 7.4763506E-005$

$M_u = 1.2308E+009$

with full section properties:

$b = 250.00$

$d = 707.00$

$d' = 43.00$

$v = 0.0023261$

$N = 9867.325$

$f_c = 24.00$

$co (5A.5, TBDY) = 0.002$

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, cc) = 0.01464812$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01464812$

$w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.03787432$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$fy = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$$af = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } ff,e = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL * t * \cos(b1) = 1.016$$

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$$psh_{\text{min}} = \text{Min}(psh_x, psh_y) = 0.00406911$$

$$psh_x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 1760.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 1360.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$fy_{we} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou_{\text{min}} = lb/ld = 1.00$$

$$su1 = 0.4 * esu1_{\text{nominal}} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_{\text{nominal}} = 0.08$,

For calculation of $esu1_{\text{nominal}}$ and $y1$, $sh1$, $ft1$, $fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1$, $sh1$, $ft1$, $fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 656.25$$

with $E_s1 = E_s = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 1.00$
 $su_2 = 0.4 * esu_2_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_2_{nominal} = 0.08$,
 For calculation of $esu_2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 656.25$
 with $E_s2 = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $su_v = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 1.00$
 $su_v = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.19051738$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.19051738$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.41602774$
 and confined core properties:
 $b = 190.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.26178921$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.26178921$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.57166216$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y_2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
 --->
 $su (4.8) = 0.39460211$
 $Mu = MRc (4.15) = 1.2308E+009$
 $u = su (4.1) = 7.4763506E-005$

 Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 673185.175$

Calculation of Shear Strength at edge 1, $Vr1 = 673185.175$

$Vr1 = VCol$ ((10.3), ASCE 41-17) = $knl * VColO$

$VColO = 673185.175$

$knl = 1$ (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)

$fc' = 24.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.48500011$

$\nu_u = 5.0286180E-008$

$d = 0.8 * h = 600.00$

$Nu = 9867.325$

$Ag = 187500.00$

From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 659734.457$

where:

$Vs1 = 164933.614$ is calculated for section web, with:

$d = 200.00$

$Av = 157079.633$

$fy = 525.00$

$s = 100.00$

$Vs1$ is multiplied by $Col1 = 1.00$

$s/d = 0.50$

$Vs2 = 494800.843$ is calculated for section flange, with:

$d = 600.00$

$Av = 157079.633$

$fy = 525.00$

$s = 100.00$

$Vs2$ is multiplied by $Col2 = 1.00$

$s/d = 0.16666667$

Vf ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $Vf(\alpha, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = b1 + 90^\circ = 90.00$

$Vf = \text{Min}(|Vf(45, \alpha)|, |Vf(-45, \alpha)|)$, with:

total thickness per orientation, $tf1 = NL * t / \text{NoDir} = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 707.00

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: $Vs + Vf \leq 488161.625$

$bw = 250.00$

Calculation of Shear Strength at edge 2, $Vr2 = 673185.175$

$Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl * VColO$

$VColO = 673185.175$

$knl = 1$ (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)

$fc' = 24.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.48484922$

$\nu_u = 5.0286180E-008$

$d = 0.8 * h = 600.00$

$Nu = 9867.325$

Ag = 187500.00
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 659734.457$

where:

$V_{s1} = 164933.614$ is calculated for section web, with:

d = 200.00

Av = 157079.633

fy = 525.00

s = 100.00

V_{s1} is multiplied by Col1 = 1.00

s/d = 0.50

$V_{s2} = 494800.843$ is calculated for section flange, with:

d = 600.00

Av = 157079.633

fy = 525.00

s = 100.00

V_{s2} is multiplied by Col2 = 1.00

s/d = 0.16666667

Vf ((11-3)-(11.4), ACI 440) = 372533.843

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 $(\cot^2 + \cot^2)\sin^2\alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha, \theta)$, 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: $\alpha_1 = \alpha_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

dfv = d (figure 11.2, ACI 440) = 707.00

ffe ((11-5), ACI 440) = 259.312

Ef = 64828.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.01

From (11-11), ACI 440: $V_s + V_f \leq 488161.625$

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\phi = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $E_{cc} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_b/d >= 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -63602.127$
Shear Force, $V_2 = 2555.206$
Shear Force, $V_3 = -59.77842$
Axial Force, $F = -10159.171$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 2261.947$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 2060.885$
Mean Diameter of Tension Reinforcement, $D_bL = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.04461699$
 $u = y + p = 0.04461699$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00581026$ ((4.29), Biskinis Phd)
 $M_y = 6.3264E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1063.965
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 3.8616E+013$
factor = 0.30
 $A_g = 262500.00$
 $f_c' = 24.00$
 $N = 10159.171$
 $E_c * I_g = 1.2872E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 8.9409093E-006$
with $f_y = 525.00$
 $d = 507.00$
 $y = 0.42091854$
 $A = 0.04080128$
 $B = 0.02737259$
with $pt = 0.01784573$
 $pc = 0.00654344$
 $pv = 0.01625945$
 $N = 10159.171$

$b = 250.00$
 $\mu = 0.08481262$
 $y_{comp} = 8.8494370E-006$
 with f_c^* (12.3, (ACI 440)) = 24.15812
 $f_c = 24.00$
 $f_l = 0.56655003$
 $b = b_{max} = 750.00$
 $h = h_{max} = 550.00$
 $A_g = 262500.00$
 $g = p_t + p_c + p_v = 0.04064862$
 $r_c = 40.00$
 $A_e/A_c = 0.16554652$
 Effective FRP thickness, $t_f = N_L * t * \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 23025.204$
 $y = 0.4209288$
 $A = 0.04043641$
 $B = 0.02721993$
 with $E_s = 200000.00$

 Calculation of ratio l_b/l_d

 Adequate Lap Length: $l_b/l_d \geq 1$

 - Calculation of p -

 From table 10-8: $p = 0.03880673$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$

shear control ratio $V_y E / V_{col} O E = 1.51499$

$d = 507.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1360.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2 * t_f / b_w * (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 * t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

$N_{UD} = 10159.171$

$A_g = 262500.00$

$f_{cE} = 24.00$

$f_{ytE} = f_{ylE} = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.04064862$

$b = 250.00$

$d = 507.00$

$f_{cE} = 24.00$

 End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 15

column C1, Floor 1

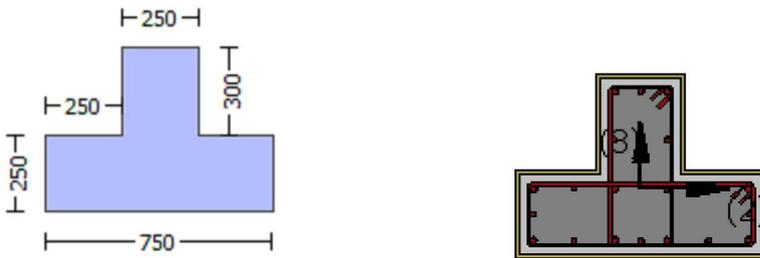
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 23025.204$

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, $f_c = f_{cm} = 24.00$

Existing material: Steel Strength, $f_s = f_{sm} = 525.00$

#####

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $Ecc = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{o,u,min} = l_b/d \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -115353.03$
Shear Force, $V_a = 59.77842$
EDGE -B-
Bending Moment, $M_b = -63602.127$
Shear Force, $V_b = -59.77842$
BOTH EDGES
Axial Force, $F = -10159.171$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 2261.947$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 2060.885$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 384616.921$
 $V_n ((10.3), ASCE 41-17) = k_n \phi V_{CoI} = 384616.921$
 $V_{CoI} = 384616.921$
 $k_n = 1.00$
 $displacement_ductility_demand = 3.6472069E-006$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ ϕV_f '
where V_f is the contribution of FRPs (11.3), ACI 440).

 $\phi = 1$ (normal-weight concrete)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.4181$
 $M_u = 63602.127$
 $V_u = 59.77842$
 $d = 0.8 \cdot h = 440.00$
 $N_u = 10159.171$
 $A_g = 137500.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 422230.053$
where:
 $V_{s1} = 290283.161$ is calculated for section web, with:
 $d = 440.00$
 $A_v = 157079.633$
 $f_y = 420.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.22727273$
 $V_{s2} = 131946.891$ is calculated for section flange, with:
 $d = 200.00$
 $A_v = 157079.633$

$f_y = 420.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.50$
 $V_f((11-3)-(11.4), ACI 440) = 267149.446$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 $\ln(11.3) \sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 507.00
 $f_{fe}((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 292293.685$
 $b_w = 250.00$

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 $\theta = 2.1191220E-008$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00581026$ ((4.29), Biskinis Phd)
 $M_y = 6.3264E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1063.965
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 3.8616E+013$
 $\text{factor} = 0.30$
 $A_g = 262500.00$
 $f_c' = 24.00$
 $N = 10159.171$
 $E_c * I_g = 1.2872E+014$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 8.9409093E-006$
 with $f_y = 525.00$
 $d = 507.00$
 $y = 0.42091854$
 $A = 0.04080128$
 $B = 0.02737259$
 with $p_t = 0.01784573$
 $p_c = 0.00654344$
 $p_v = 0.01625945$
 $N = 10159.171$
 $b = 250.00$
 $\theta = 0.08481262$
 $y_{comp} = 8.8494370E-006$
 with $f_c' (12.3, (ACI 440)) = 24.15812$
 $f_c = 24.00$
 $f_l = 0.56655003$
 $b = b_{max} = 750.00$
 $h = h_{max} = 550.00$
 $A_g = 262500.00$
 $g = p_t + p_c + p_v = 0.04064862$

$r_c = 40.00$
 $A_e/A_c = 0.16554652$
Effective FRP thickness, $t_f = NL * t * \cos(b1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 23025.204$
 $y = 0.4209288$
 $A = 0.04043641$
 $B = 0.02721993$
with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

End Of Calculation of Shear Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 16

column C1, Floor 1

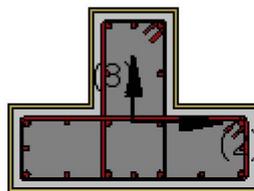
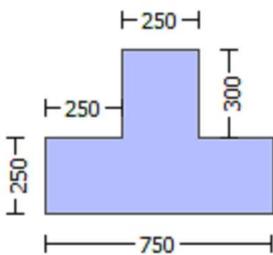
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rctcs

Constant Properties

```

Knowledge Factor,  $\phi = 1.00$ 
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 24.00$ 
Existing material of Primary Member: Steel Strength,  $f_s = f_{sm} = 525.00$ 
Concrete Elasticity,  $E_c = 23025.204$ 
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,  $f_s = 1.25 \cdot f_{sm} = 656.25$ 
#####
Max Height,  $H_{max} = 550.00$ 
Min Height,  $H_{min} = 250.00$ 
Max Width,  $W_{max} = 750.00$ 
Min Width,  $W_{min} = 250.00$ 
Eccentricity,  $Ecc = 250.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.30771
Element Length,  $L = 3000.00$ 
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou, min} >= 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $NoDir = 1$ 
Fiber orientations,  $bi = 0.00^\circ$ 
Number of layers,  $NL = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
At local axis: 3
EDGE -A-
Shear Force,  $V_a = 0.00020794$ 
EDGE -B-
Shear Force,  $V_b = -0.00020794$ 
BOTH EDGES
Axial Force,  $F = -9867.325$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $A_{st} = 0.00$ 
-Compression:  $A_{sc} = 5152.212$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $A_{st, ten} = 2261.947$ 
-Compression:  $A_{sl, com} = 829.3805$ 
-Middle:  $A_{sl, mid} = 2060.885$ 
-----
-----

Calculation of Shear Capacity ratio,  $V_e/V_r = 1.51499$ 
Member Controlled by Shear ( $V_e/V_r > 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 645516.591$ 
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 9.6827E+008$ 
 $M_{u1+} = 9.6827E+008$ , 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
 $M_{u1-} = 8.4161E+008$ , 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 9.6827E+008$$

$M_{u2+} = 9.6827E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 8.4161E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 2.0901588E-005$$

$$M_u = 9.6827E+008$$

with full section properties:

$$b = 250.00$$

$$d = 507.00$$

$$d' = 43.00$$

$$v = 0.0032437$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$\omega (5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \phi_{cu} = 0.01464812$$

$$\phi_{cu} \text{ (5.4c), TB DY} = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07767542$$

where $\phi_f = a_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.03787432$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$\phi_{fy} = 0.03787432$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00406911$$

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00406911$$

$$Lstir (\text{Length of stirrups along Y}) = 1760.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 262500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00526591$$

$$Lstir (\text{Length of stirrups along X}) = 1360.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 262500.00$$

$$s = 100.00$$

$$fywe = 656.25$$

$$fce = 24.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs1 = fs = 656.25$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 787.50$$

$$fy2 = 656.25$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 1.00$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs2 = fs = 656.25$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 787.50$$

$$fyv = 656.25$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = fs = 656.25$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.48796927$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.17892207$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.44459423$$

and confined core properties:

$$b = 190.00$$

$$d = 477.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 31.38503$$

$$c_c (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.68244627$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.2502303$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.62178438$$

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 not satisfied

---->

Case/Assumption Rejected.

---->

New Case/Assumption: Unconfined full section - Spalling of concrete cover

' satisfies Eq. (4.4)

---->

$v < s_{y1}$ - LHS eq.(4.7) is not satisfied

---->

$v < v_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

$$c_u (4.10) = 0.43574957$$

$$M_{Rc} (4.17) = 8.0482E+008$$

---->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover

In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o

- $N, 1, 2, v$ normalised to b_o*d_o , instead of $b*d$

- - parameters of confined concrete, f_{cc}, c_c , used in lieu of f_c, e_c

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

$$^*c_u (4.10) = 0.5092345$$

$$M_{Ro} (4.17) = 9.6827E+008$$

---->

$$u = c_u (4.2) = 2.0901588E-005$$

$$M_u = M_{Ro}$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u1} -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 7.5354574E-005$$

$$Mu = 8.4161E+008$$

with full section properties:

$$b = 750.00$$

$$d = 507.00$$

$$d' = 43.00$$

$$v = 0.00108123$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$\alpha (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01464812$$

$$\omega_e \text{ ((5.4c), TBDY) } = \alpha s_e * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07767542$$

where $\phi = \alpha f_p^* f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 39233.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$\phi_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 0.00$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_s = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,\text{min}} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$$

$$p_{sh,x} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 1760.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 262500.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 1360.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 262500.00$$

$$s = 100.00$$

$$fy_{we} = 656.25$$

$$f_{ce} = 24.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.0050771$

$$c = \text{confinement factor} = 1.30771$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 1.00$$

$$su_1 = 0.4 * esu_{1, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: $esu_{1, \text{nominal}} = 0.08$,

For calculation of $esu_{1, \text{nominal}}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 656.25$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/lb, \min = 1.00$$

$$su_2 = 0.4 * esu_{2, \text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: $esu_{2, \text{nominal}} = 0.08$,

For calculation of $esu_{2, \text{nominal}}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_2 = fs = 656.25$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 1.00$$

$$suv = 0.4 * esuv_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$$

From table 5A.1, TBDY: $esuv_{\text{nominal}} = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{\text{nominal}}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $fsy_v = fsv/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 656.25$$

$$\text{with } Es_v = Es = 200000.00$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.05964069$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.16265642$$

$$v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.14819808$$

and confined core properties:

$$b = 690.00$$

$$d = 477.00$$

$$d' = 13.00$$

$$fcc (5A.2, \text{TBDY}) = 31.38503$$

$$cc (5A.5, \text{TBDY}) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.068904$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.18791999$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.17121599$$

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

--->

$$s_u(4.8) = 0.16240824$$

$$M_u = M_{Rc}(4.15) = 8.4161E+008$$

$$u = s_u(4.1) = 7.5354574E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2+}

Calculation of ultimate curvature κ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 2.0901588E-005$$

$$M_u = 9.6827E+008$$

with full section properties:

$$b = 250.00$$

$$d = 507.00$$

$$d' = 43.00$$

$$v = 0.0032437$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$\alpha(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \kappa_u: \kappa_u^* = \text{shear_factor} * \text{Max}(\kappa_u, \kappa_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \kappa_u = 0.01464812$$

$$\omega_e(5.4c, TBDY) = \alpha * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

where $f = \alpha * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.35771528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with $\text{Shear_factor} = 1.00$

$lo/lou,min = lb/l_d = 1.00$

$su_1 = 0.4 * esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with $\text{Shear_factor} = 1.00$

$lo/lou,min = lb/l_{b,min} = 1.00$

$su_2 = 0.4 * esu_{2,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 γ_v , shv,ftv,fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 γ_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 $fsv = fs = 656.25$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.48796927$
 $2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.17892207$
 $v = Asl_{mid}/(b*d)*(fsv/fc) = 0.44459423$

and confined core properties:

$b = 190.00$
 $d = 477.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = Asl_{ten}/(b*d)*(fs_1/fc) = 0.68244627$
 $2 = Asl_{com}/(b*d)*(fs_2/fc) = 0.2502303$
 $v = Asl_{mid}/(b*d)*(fsv/fc) = 0.62178438$

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 not satisfied

---->

Case/Assumption Rejected.

---->

New Case/Assumption: Unconfined full section - Spalling of concrete cover
 ' satisfies Eq. (4.4)

---->

$v < s_{y1}$ - LHS eq.(4.7) is not satisfied

---->

$v < v_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

$cu (4.10) = 0.43574957$
 $MRc (4.17) = 8.0482E+008$

---->

New Case/Assumption: Ultimate curvature of confined core after spalling of concrete cover
 In expressions below, the following modifications have been made

- b, d, d' replaced by geometric parameters of the core: b_o, d_o, d'_o
- $N, 1, 2, v$ normalised to b_o*d_o , instead of $b*d$
- parameters of confined concrete, f_{cc}, cc , used in lieu of f_c, c

---->

Subcase: Rupture of tension steel

---->

$v^* < v^*_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v^* < v^*_{s,c}$ - LHS eq.(4.5) is not satisfied

---->

Subcase rejected

---->

New Subcase: Failure of compression zone

---->

$v^* < v^*_{c,y2}$ - LHS eq.(4.6) is not satisfied

---->

$v^* < v^*_{c,y1}$ - RHS eq.(4.6) is satisfied

---->

$*cu (4.10) = 0.5092345$
 $MRO (4.17) = 9.6827E+008$

---->

$u = cu (4.2) = 2.0901588E-005$
 $Mu = MRO$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_2

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 7.5354574E-005$$

$$\mu_2 = 8.4161E+008$$

with full section properties:

$$b = 750.00$$

$$d = 507.00$$

$$d' = 43.00$$

$$v = 0.00108123$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$\alpha_{co} \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear_factor} * \text{Max}(\mu_2, \mu_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_2 = 0.01464812$$

$$\mu_2 \text{ (5.4c), TBDY} = \alpha_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

where $f_x = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00406911$$

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00406911$$

$$Lstir (\text{Length of stirrups along Y}) = 1760.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 262500.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00526591$$

$$Lstir (\text{Length of stirrups along X}) = 1360.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 262500.00$$

$$s = 100.00$$

$$fywe = 656.25$$

$$fce = 24.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 787.50$$

$$fy1 = 656.25$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/d = 1.00$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 656.25$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 787.50$$

$$fy2 = 656.25$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 1.00$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 656.25$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 787.50$$

$$fyv = 656.25$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/d = 1.00$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 656.25$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.05964069$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.16265642$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.14819808$$

and confined core properties:

$$b = 690.00$$

$$d = 477.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 31.38503$$

$$c_c (5A.5, TBDY) = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.068904$$

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.18791999$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.17121599$$

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

--->

$$s_u (4.8) = 0.16240824$$

$$M_u = M_{Rc} (4.15) = 8.4161E+008$$

$$u = s_u (4.1) = 7.5354574E-005$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 426086.999$

Calculation of Shear Strength at edge 1, $V_{r1} = 426086.999$

$$V_{r1} = V_{CoI} ((10.3), ASCE 41-17) = k_{nl} * V_{CoI0}$$

$$V_{CoI0} = 426086.999$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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 (normal-weight concrete)

$$f_c' = 24.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 867.1065$$

$$V_u = 0.00020794$$

$$d = 0.8 * h = 440.00$$

$$N_u = 9867.325$$

$$A_g = 137500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 527787.566$$

where:

$V_{s1} = 362853.951$ is calculated for section web, with:

$$d = 440.00$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

V_{s1} is multiplied by $Col1 = 1.00$

$$s/d = 0.22727273$$

$V_{s2} = 164933.614$ is calculated for section flange, with:

$$d = 200.00$$

$$A_v = 157079.633$$

$$f_y = 525.00$$

$$s = 100.00$$

V_{s2} is multiplied by $Col2 = 1.00$

$$s/d = 0.50$$

$$V_f ((11-3)-(11.4), ACI 440) = 267149.446$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $tf_1 = NL \cdot t / \text{NoDir} = 1.016$

$df_v = d$ (figure 11.2, ACI 440) = 507.00

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: $V_s + V_f \leq 357985.191$

$bw = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 426086.999$

$V_{r2} = V_{CoI}$ ((10.3), ASCE 41-17) = $knI \cdot V_{CoI0}$

$V_{CoI0} = 426086.999$

$knI = 1$ (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).

$\gamma_c = 1$ (normal-weight concrete)

$f_c' = 24.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 867.1065$

$V_u = 0.00020794$

$d = 0.8 \cdot h = 440.00$

$N_u = 9867.325$

$A_g = 137500.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 527787.566$

where:

$V_{s1} = 362853.951$ is calculated for section web, with:

$d = 440.00$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.22727273$

$V_{s2} = 164933.614$ is calculated for section flange, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 525.00$

$s = 100.00$

V_{s2} is multiplied by $Col2 = 1.00$

$s/d = 0.50$

V_f ((11-3)-(11.4), ACI 440) = 267149.446

$f = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $tf_1 = NL \cdot t / \text{NoDir} = 1.016$

$df_v = d$ (figure 11.2, ACI 440) = 507.00

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: $V_s + V_f \leq 357985.191$

$bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
Concrete Elasticity, $E_c = 23025.204$
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, $f_s = 1.25 \cdot f_{sm} = 656.25$

Max Height, $H_{max} = 550.00$
Min Height, $H_{min} = 250.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 250.00$
Eccentricity, $Ecc = 250.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.30771
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} > 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 5.0286180E-008$
EDGE -B-
Shear Force, $V_b = -5.0286180E-008$
BOTH EDGES
Axial Force, $F = -9867.325$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 5152.212$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 1231.504$

-Compression: $Asl,com = 1231.504$
-Middle: $Asl,mid = 2689.203$

Calculation of Shear Capacity ratio , $Ve/Vr = 1.21891$

Member Controlled by Shear ($Ve/Vr > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $Ve = (Mpr1 + Mpr2)/ln = 820555.407$

with

$Mpr1 = \text{Max}(Mu1+, Mu1-) = 1.2308E+009$

$Mu1+ = 1.2308E+009$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu1- = 1.2308E+009$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$Mpr2 = \text{Max}(Mu2+, Mu2-) = 1.2308E+009$

$Mu2+ = 1.2308E+009$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$Mu2- = 1.2308E+009$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of $Mu1+$

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 7.4763506E-005$

$Mu = 1.2308E+009$

with full section properties:

$b = 250.00$

$d = 707.00$

$d' = 43.00$

$v = 0.0023261$

$N = 9867.325$

$fc = 24.00$

$co (5A.5, TBDY) = 0.002$

Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01464812$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01464812$

$we ((5.4c), TBDY) = ase * sh, \text{min} * fywe / fce + \text{Min}(fx, fy) = 0.07767542$

where $f = af * pf * ffe / fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$fx = 0.03787432$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.14946032$

with Unconfined area = $((bmax-2R)^2 + (hmax-2R)^2) / 3 = 39233.333$

$bmax = 750.00$

$hmax = 550.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ffe = 748.2496$

$fy = 0.03787432$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.14946032$

with Unconfined area = $((bmax-2R)^2 + (hmax-2R)^2) / 3 = 0.00$

$bmax = 750.00$

$hmax = 550.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ffe = 748.2496$

$R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

$fu,f = 1055.00$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.35771528$$

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.

$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00406911$$

$$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 1760.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 262500.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$$

$$L_{stir} \text{ (Length of stirrups along X)} = 1360.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 262500.00$$

$$s = 100.00$$

$$f_{ywe} = 656.25$$

$$f_{ce} = 24.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.0050771$$

$$c = \text{confinement factor} = 1.30771$$

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 787.50$$

$$fy_1 = 656.25$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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.

$$\text{with } fs_1 = fs = 656.25$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 787.50$$

$$fy_2 = 656.25$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_{b,min} = 1.00$$

$$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$$

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.

$$\text{with } fs_2 = fs = 656.25$$

$$\text{with } Es_2 = Es = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 787.50$$

$$fy_v = 656.25$$

suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19051738

2 = Asl,com/(b*d)*(fs2/fc) = 0.19051738

v = Asl,mid/(b*d)*(fsv/fc) = 0.41602774

and confined core properties:

b = 190.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

1 = Asl,ten/(b*d)*(fs1/fc) = 0.26178921

2 = Asl,com/(b*d)*(fs2/fc) = 0.26178921

v = Asl,mid/(b*d)*(fsv/fc) = 0.57166216

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) = 0.39460211

Mu = MRc (4.15) = 1.2308E+009

u = su (4.1) = 7.4763506E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 7.4763506E-005

Mu = 1.2308E+009

with full section properties:

b = 250.00

d = 707.00

d' = 43.00

v = 0.0023261

N = 9867.325

fc = 24.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01464812

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01464812

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.07767542

where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.03787432

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$

$b_{max} = 750.00$

$h_{max} = 550.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff,e = 748.2496$

$f_y = 0.03787432$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.14946032$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 750.00$

$h_{max} = 550.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $ff,e = 748.2496$

$R = 40.00$

Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.35771528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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$A_{conf,max} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 137025.00$ 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.

$A_{noConf} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

$s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $cc = 0.0050771$

c = confinement factor = 1.30771

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 787.50$

$fy1 = 656.25$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/ld = 1.00$

$su1 = 0.4*esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1$, $sh1$, $ft1$, $fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1$, $sh1$, $ft1$, $fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $f_{s1} = f_s = 656.25$
 with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 787.50$
 $fy_2 = 656.25$
 $su_2 = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 1.00$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 656.25$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 787.50$
 $fy_v = 656.25$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 1.00$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 656.25$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.19051738$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.19051738$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.41602774$
 and confined core properties:
 $b = 190.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 31.38503$
 $cc (5A.5, TBDY) = 0.0050771$
 $c = \text{confinement factor} = 1.30771$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.26178921$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.26178921$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.57166216$
 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
 --->
 $su (4.8) = 0.39460211$
 $Mu = MR_c (4.15) = 1.2308E+009$
 $u = su (4.1) = 7.4763506E-005$

 Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 7.4763506E-005$$

$$\mu_u = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$\alpha (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.01464812$$

$$\mu_c \text{ ((5.4c), TBDY) } = \alpha * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07767542$$

where $f = \alpha * \rho_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 39233.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$f_y = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$\alpha_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 750.00$$

$$h_{\max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.35771528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

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$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00406911$$

$$\text{psh}_x \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00406911$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 1760.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 262500.00$$

$$\text{psh}_y \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00526591$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 1360.00$$

Astir (stirrups area) = 78.53982
Asec (section area) = 262500.00

s = 100.00
fywe = 656.25
fce = 24.00

From ((5.A.5), TBDY), TBDY: cc = 0.0050771
c = confinement factor = 1.30771

y1 = 0.0025
sh1 = 0.008
ft1 = 787.50
fy1 = 656.25
su1 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es1 = Es = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 787.50
fy2 = 656.25
su2 = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Es2 = Es = 200000.00

yv = 0.0025
shv = 0.008
ftv = 787.50
fyv = 656.25
suv = 0.032

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 1.00

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 = 656.25

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.19051738

2 = Asl,com/(b*d)*(fs2/fc) = 0.19051738

v = Asl,mid/(b*d)*(fsv/fc) = 0.41602774

and confined core properties:

b = 190.00
d = 677.00
d' = 13.00

fcc (5A.2, TBDY) = 31.38503

cc (5A.5, TBDY) = 0.0050771

c = confinement factor = 1.30771

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.26178921$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.26178921$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.57166216$$

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

--->

$$s_u(4.8) = 0.39460211$$

$$M_u = M_{Rc}(4.15) = 1.2308E+009$$

$$u = s_u(4.1) = 7.4763506E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of M_{u2}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 7.4763506E-005$$

$$M_u = 1.2308E+009$$

with full section properties:

$$b = 250.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.0023261$$

$$N = 9867.325$$

$$f_c = 24.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01464812$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01464812$$

$$\phi_{cc} \text{ ((5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07767542$$

where $\phi_f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 39233.333$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 748.2496$$

$$\phi_{fy} = 0.03787432$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.14946032$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 750.00$$

$$h_{max} = 550.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 748.2496$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

u,f = 0.015

ase = $\text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.35771528$

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.

$A_{\text{conf,max}} = 188100.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 137025.00$ 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.

$A_{\text{noConf}} = 95733.333$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00406911$

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00406911$

L_{stir} (Length of stirrups along Y) = 1760.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00526591$

L_{stir} (Length of stirrups along X) = 1360.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 262500.00

 $s = 100.00$

$f_{ywe} = 656.25$

$f_{ce} = 24.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 787.50$

$fy_1 = 656.25$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1 , sh_1 , ft_1 , fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 656.25$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 787.50$

$fy_2 = 656.25$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 * esu_{2,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,

For calculation of $esu_{2,nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2 , sh_2 , ft_2 , fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 656.25$

with $Es_2 = Es = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 787.50$

$fy_v = 656.25$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_0/l_{0,min} = l_b/l_d = 1.00$

$s_{uv} = 0.4 \cdot e_{suv,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv,nominal}$ and γ_v , $sh_v, ft_v, f_{y,v}$, it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, 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 $f_{sv} = f_s = 656.25$

with $E_{sv} = E_s = 200000.00$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.19051738$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.19051738$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.41602774$

and confined core properties:

$b = 190.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 31.38503$

$cc (5A.5, TBDY) = 0.0050771$

$c = \text{confinement factor} = 1.30771$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.26178921$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.26178921$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.57166216$

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

$s_u (4.8) = 0.39460211$

$M_u = MR_c (4.15) = 1.2308E+009$

$u = s_u (4.1) = 7.4763506E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 673185.175$

Calculation of Shear Strength at edge 1, $V_{r1} = 673185.175$

$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Co10}$

$V_{Co10} = 673185.175$

$k_{nl} = 1$ (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)

$f_c' = 24.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 0.48500011$

$V_u = 5.0286180E-008$

$d = 0.8 \cdot h = 600.00$

$N_u = 9867.325$

$A_g = 187500.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 659734.457$

where:

$V_{s1} = 164933.614$ is calculated for section web, with:

$d = 200.00$

$A_v = 157079.633$

$f_y = 525.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 494800.843$ is calculated for section flange, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.16666667$
 V_f ((11-3)-(11.4), ACI 440) = 372533.843
 $f = 0.95$, 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, $t_{f1} = NL * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 707.00
 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: $V_s + V_f \leq 488161.625$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 673185.175$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$
 $V_{Col0} = 673185.175$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} + f * V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 24.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/\lambda d = 2.00$
 $\mu_u = 0.48484922$
 $V_u = 5.0286180E-008$
 $d = 0.8 * h = 600.00$
 $N_u = 9867.325$
 $A_g = 187500.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 659734.457$
 where:
 $V_{s1} = 164933.614$ is calculated for section web, with:
 $d = 200.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.50$
 $V_{s2} = 494800.843$ is calculated for section flange, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 525.00$
 $s = 100.00$
 V_{s2} is multiplied by $Col2 = 1.00$
 $s/d = 0.16666667$
 V_f ((11-3)-(11.4), ACI 440) = 372533.843
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ$ and $\alpha = 90^\circ$

$V_f = \text{Min}(|V_f(45, 90)|, |V_f(-45, 90)|)$, with:

total thickness per orientation, $t_f = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 488161.625$

$b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column TC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1
At local axis: 3
Integration Section: (b)
Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 550.00$

Min Height, $H_{min} = 250.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 250.00$

Eccentricity, $E_{cc} = 250.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b / l_d > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $\text{NoDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 87395.69$

Shear Force, $V_2 = 2555.206$

Shear Force, $V_3 = -59.77842$

Axial Force, $F = -10159.171$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5152.212$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{st,ten} = 1231.504$

-Compression: $A_{sc,com} = 1231.504$

-Middle: $A_{st,mid} = 2689.203$

Mean Diameter of Tension Reinforcement, $D_bL = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $\phi_{u,R} = \phi_u = 0.0405526$

$\phi_u = \phi_y + \phi_p = 0.0405526$

- Calculation of ϕ_y -

$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00103477$ ((4.29), Biskinis Phd))

$M_y = 6.5614E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 6.3409E+013$

factor = 0.30

$A_g = 262500.00$

$f_c' = 24.00$

$N = 10159.171$

$E_c * I_g = 2.1136E+014$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

$\phi_y = \text{Min}(\phi_{y,ten}, \phi_{y,com})$

$\phi_{y,ten} = 5.4982839E-006$

with $f_y = 525.00$

$d = 707.00$

$\phi_y = 0.3247218$

$A = 0.0292592$

$B = 0.01557079$

with $p_t = 0.00696749$

$p_c = 0.00696749$

$p_v = 0.01521473$

$N = 10159.171$

$b = 250.00$

$\phi_y = 0.06082037$

$\phi_{y,comp} = 8.2388357E-006$

with f_c^* (12.3, (ACI 440)) = 24.16756

$f_c = 24.00$

$f_l = 0.56655003$

$b = b_{max} = 750.00$

$h = h_{max} = 550.00$

$A_g = 262500.00$

$g = p_t + p_c + p_v = 0.02914971$

$r_c = 40.00$

$A_e / A_c = 0.17542991$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 23025.204$

$\phi_y = 0.32435206$

$A = 0.0289976$

$B = 0.01546131$

with $E_s = 200000.00$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of ρ -

From table 10-8: $\rho = 0.03951783$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/d < 1$

shear control ratio $V_y E / V_{CoI} E = 1.21891$

$d = 707.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 1760.00$, 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.

$NUD = 10159.171$

$A_g = 262500.00$

$f_{cE} = 24.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.02914971$

$b = 250.00$

$d = 707.00$

$f_{cE} = 24.00$

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (b)