

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

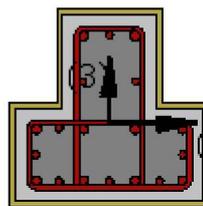
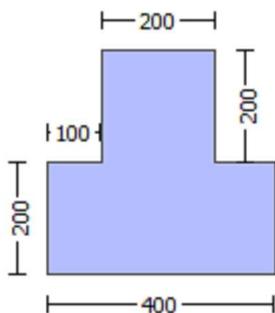
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

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, $f_c = f_{c_lower_bound} = 10.00$

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

Concrete Elasticity, $E_c = 18203.022$

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$

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

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Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -8.4385E+006$

Shear Force, $V_a = -2811.342$

EDGE -B-

Bending Moment, $M_b = -136.3192$

Shear Force, $V_b = 2811.342$

BOTH EDGES

Axial Force, $F = -4735.965$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 2375.044$

-Compression: $A_{sc} = 2777.168$

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 $V_R = \phi V_n = 144111.087$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 160123.429$

$V_{CoI} = 160123.429$

$k_n = 1.00$

$displacement_ductility_demand = 0.01556566$

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)

$f_c' = 10.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 8.4385E+006$$

$$V_u = 2811.342$$

$$d = 0.8 \cdot h = 320.00$$

$$N_u = 4735.965$$

$$A_g = 80000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 0.00$$

where:

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

$$d = 160.00$$

$$A_v = 157079.633$$

$$f_y = 400.00$$

$$s = 380.00$$

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

$$s/d = 2.375$$

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

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 400.00$$

$$s = 380.00$$

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

$$s/d = 1.1875$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 188111.148$$

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

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

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

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

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

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

$$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|), \text{ with:}$$

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 357.00$$

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 134445.642$$

$$b_w = 200.00$$

displacement ductility demand is calculated as δ_u / y

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

From analysis, chord rotation $\theta = 0.00032458$

$$y = (M_y \cdot L_s / 3) / E_{eff} = 0.02085204 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 1.3657E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 \cdot L \text{ and } L_s < 2 \cdot L) = 3001.586$$

$$\text{From table 10.5, ASCE 41-17: } E_{eff} = \text{factor} \cdot E_c \cdot I_g = 6.5531E+012$$

$$\text{factor} = 0.30$$

$$A_g = 120000.00$$

$$f_c' = 15.00$$

$$N = 4735.965$$

$$E_c \cdot I_g = 2.1844E+013$$

Calculation of Yielding Moment M_y

Calculation of δ_u and M_y according to Annex 7 -

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

$$y_{ten} = 5.8874222E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 235.317$$

$d = 357.00$
 $y = 0.44020389$
 $A = 0.07244171$
 $B = 0.04070755$
 with $pt = 0.01724796$
 $pc = 0.01724796$
 $pv = 0.03766391$
 $N = 4735.965$
 $b = 200.00$
 $" = 0.12044818$
 $y_{comp} = 1.0162905E-005$
 with $fc^* (12.3, (ACI 440)) = 16.12972$
 $fc = 15.00$
 $fl = 0.93147527$
 $b = b_{max} = 400.00$
 $h = h_{max} = 400.00$
 $Ag = 120000.00$
 $g = pt + pc + pv = 0.07215983$
 $rc = 40.00$
 $Ae/Ac = 0.38686758$
 Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 18203.022$
 $y = 0.43961224$
 $A = 0.0719519$
 $B = 0.04042568$
 with $Es = 200000.00$

 Calculation of ratio lb/ld

 Lap Length: $ld/ld, \min = 0.27567359$

$lb = 300.00$

$ld = 1088.244$

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

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $fy = 444.44$

$fc' = 15.00$, but $fc^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 24.02082$

$K_{tr} = 0.82673491$

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

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

$s = 380.00$

$n = 20.00$

 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

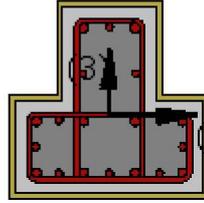
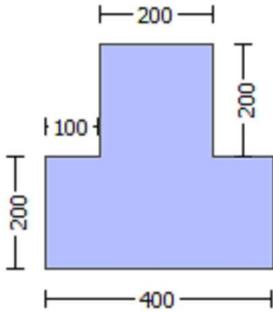
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

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, $\gamma = 0.90$

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

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

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

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

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Note: Especially for the calculation of moment strengths,

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

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

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Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $E_{cc} = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.27578

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$
Number of directions, NoDir = 1
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 0.01054019$
EDGE -B-
Shear Force, $V_b = -0.01054019$
BOTH EDGES
Axial Force, $F = -4737.328$
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: $A_{sl,mid} = 2060.885$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.82694402$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 162085.836$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.4313E+008$
 $\mu_{u1+} = 2.4313E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 1.2706E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.4313E+008$
 $\mu_{u2+} = 2.4313E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $\mu_{u2-} = 1.2706E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 2.6161250E-005$
 $\mu_u = 2.4313E+008$

with full section properties:

$b = 200.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00442328$

$N = 4737.328$

$f_c = 15.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of α_{cu} : $\alpha_{cu}^* = \text{shear_factor} * \text{Max}(\alpha_{cu}, \alpha_{cc}) = 0.018$

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

From (5.4b), TBDY: $\alpha_{cu} = 0.018$

where α_{cu} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

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

$f_x = 0.15303423$

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

$$af = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.01016$$

$$bw = 200.00$$

$$\text{effective stress from (A.35), } ff,e = 524.0792$$

$$fy = 0.15303423$$

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

$$af = 0.43111111$$

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

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.01016$$

$$bw = 200.00$$

$$\text{effective stress from (A.35), } ff,e = 524.0792$$

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$$psh_{\min} = \text{Min}(psh_x, psh_y) = 0.00165347$$

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

$$psh_x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 960.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 120000.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 960.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$fy_{we} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y1 = 0.0010562$$

$$sh1 = 0.00365026$$

$$ft1 = 304.185$$

$$fy1 = 253.4875$$

$$su1 = 0.00365026$$

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

$$lo/lou_{\min} = lb/ld = 0.22053887$$

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

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

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.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_1 = fs = 253.4875$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.0010562$
 $sh_2 = 0.00365026$
 $ft_2 = 304.185$
 $fy_2 = 253.4875$
 $su_2 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/lb, min = 0.22053887$
 $su_2 = 0.4 \cdot esu_2, nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_2, nominal = 0.08$,
 For calculation of $esu_2, nominal$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_2 = fs = 253.4875$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.0010562$
 $sh_v = 0.00365026$
 $ft_v = 304.185$
 $fy_v = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/d = 0.22053887$
 $suv = 0.4 \cdot esuv, nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv, nominal = 0.08$,
 considering characteristic value $fsyv = fs_v/1.2$, from table 5.1, TBDY
 For calculation of $esuv, nominal$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fs_v/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_v = fs = 253.4875$
 with $Es_v = Es = 200000.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs_1 / fc) = 0.53536441$
 $2 = Asl, com / (b \cdot d) \cdot (fs_2 / fc) = 0.19630028$
 $v = Asl, mid / (b \cdot d) \cdot (fs_v / fc) = 0.48777647$

and confined core properties:

$b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = Asl, ten / (b \cdot d) \cdot (fs_1 / fc) = 0.83497202$
 $2 = Asl, com / (b \cdot d) \cdot (fs_2 / fc) = 0.30615641$
 $v = Asl, mid / (b \cdot d) \cdot (fs_v / fc) = 0.76075229$

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

$cu (4.10) = 0.46564051$

$MRC (4.17) = 2.0934E+008$

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

From (5.4b), TBDY: $c_u = 0.018$

where ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

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

 $f_x = 0.15303423$

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

$af = 0.43111111$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $ff_e = 524.0792$

 $f_y = 0.15303423$

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

$af = 0.43111111$

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

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $ff_e = 524.0792$

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

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

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $s = 380.00$

$fy_{we} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

$c = \text{confinement factor} = 1.27578$

$y1 = 0.0010562$

$sh1 = 0.00365026$

$ft1 = 304.185$

$fy1 = 253.4875$

$su1 = 0.00365026$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.22053887

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, ASCE 41-17.

with fs1 = fs = 253.4875

with Es1 = Es = 200000.00

y2 = 0.0010562

sh2 = 0.00365026

ft2 = 304.185

fy2 = 253.4875

su2 = 0.00365026

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.22053887

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

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

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

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs2 = fs = 253.4875

with Es2 = Es = 200000.00

yv = 0.0010562

shv = 0.00365026

ftv = 304.185

fyv = 253.4875

suv = 0.00365026

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.22053887

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, ASCE 41-17.

with fsv = fs = 253.4875

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09815014

2 = Asl,com/(b*d)*(fs2/fc) = 0.26768221

v = Asl,mid/(b*d)*(fsv/fc) = 0.24388823

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

c = confinement factor = 1.27578

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1260644

2 = Asl,com/(b*d)*(fs2/fc) = 0.34381201

v = Asl,mid/(b*d)*(fsv/fc) = 0.31325094

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.23431248

Mu = MRc (4.14) = 1.2706E+008

u = su (4.1) = 1.3353763E-005

Calculation of ratio lb/d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$

$l_d = 1360.304$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

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

$f_c' = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 24.02082$

$K_{tr} = 0.82673491$

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

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

$s = 380.00$

$n = 20.00$

Calculation of μ_{2+}

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

$\mu = 2.6161250E-005$

$\mu = 2.4313E+008$

with full section properties:

$b = 200.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00442328$

$N = 4737.328$

$f_c = 15.00$

c_o (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, c_c) = 0.018$

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

From (5.4b), TBDY: $\mu = 0.018$

we ((5.4c), TBDY) = $a_s e^* \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

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

$f_x = 0.15303423$

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

$a_f = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

$f_y = 0.15303423$

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

$a_f = 0.43111111$

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

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$$u,f = 0.015$$

$$ase = \text{Max}(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.00$$

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 = 75600.00 is the confined core 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 = 0.00 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 = 33066.667 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00165347$$

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

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir \text{ (Length of stirrups along Y)} = 960.00$$

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

$$Asec \text{ (section area)} = 120000.00$$

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir \text{ (Length of stirrups along X)} = 960.00$$

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

$$Asec \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y1 = 0.0010562$$

$$sh1 = 0.00365026$$

$$ft1 = 304.185$$

$$fy1 = 253.4875$$

$$su1 = 0.00365026$$

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

$$lo/lou,min = lb/l_d = 0.22053887$$

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

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

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

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = fs = 253.4875$$

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

$$y2 = 0.0010562$$

$$sh2 = 0.00365026$$

$$ft2 = 304.185$$

$$fy2 = 253.4875$$

$$su2 = 0.00365026$$

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

$$lo/lou,min = lb/l_{b,min} = 0.22053887$$

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

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

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

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = fs = 253.4875$$

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

$$yv = 0.0010562$$

$$shv = 0.00365026$$

$$ftv = 304.185$$

$f_{yv} = 253.4875$
 $s_{uv} = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.22053887$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5,5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $f_{sv} = f_s = 253.4875$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.53536441$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.19630028$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.48777647$
 and confined core properties:
 $b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.83497202$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.30615641$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.76075229$
 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
 --->
 $cu (4.10) = 0.46564051$
 $MRC (4.17) = 2.0934E+008$
 --->
 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}, 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
 --->
 $*cu (4.10) = 0.55615794$

$$M_{Ro} (4.17) = 2.4313E+008$$

--->

$$u = c_u (4.2) = 2.6161250E-005$$

$$M_u = M_{Ro}$$

Calculation of ratio l_b/l_d

$$\text{Lap Length: } l_b/l_d = 0.22053887$$

$$l_b = 300.00$$

$$l_d = 1360.304$$

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

$$= 1$$

$$d_b = 18.00$$

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

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

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

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

$$s = 380.00$$

$$n = 20.00$$

Calculation of M_u

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

$$u = 1.3353763E-005$$

$$M_u = 1.2706E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00221164$$

$$N = 4737.328$$

$$f_c = 15.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$\text{we ((5.4c), TBDY) } = a_s e^* \text{ sh, min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

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

$$f_x = 0.15303423$$

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

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

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

$$a_f = 0.43111111$$

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

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

bw = 200.00
effective stress from (A.35), $f_{f,e} = 524.0792$

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

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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., 10.11061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

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

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
 L_{stir} (Length of stirrups along Y) = 960.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 120000.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
 L_{stir} (Length of stirrups along X) = 960.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 120000.00

s = 380.00
 $f_{ywe} = 555.55$
 $f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$
c = confinement factor = 1.27578

$y_1 = 0.0010562$
 $sh_1 = 0.00365026$
 $ft_1 = 304.185$
 $fy_1 = 253.4875$
 $su_1 = 0.00365026$

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

$l_o/l_{o,min} = l_b/l_d = 0.22053887$

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

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

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

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.0010562$
 $sh_2 = 0.00365026$
 $ft_2 = 304.185$
 $fy_2 = 253.4875$
 $su_2 = 0.00365026$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$

$su_2 = 0.4 * esu2_{nominal}$ ((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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 196005.816$

Calculation of Shear Strength at edge 1, $V_{r1} = 227350.021$

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

$V_{Col0} = 227350.021$

$knl = 1$ (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).

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

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 3.21769$

$\nu_u = 0.01054019$

$d = 0.8 * h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

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

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

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

$s/d = 1.1875$

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

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

$s/d = 2.375$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, 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: $\theta = 45^\circ$ and $\alpha = 90^\circ$

$V_f = \text{Min}(|V_f(45, 90)|, |V_f(-45, 90)|)$, with:

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 196005.816$

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

$V_{Col0} = 196005.816$

$knl = 1$ (zero step-static loading)

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

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

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 23.99609$

$\nu_u = 0.01054019$

$d = 0.8 * h = 320.00$

Nu = 4737.328
Ag = 80000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 0.00

where:

Vs1 = 0.00 is calculated for section web, with:

d = 320.00
Av = 157079.633
fy = 444.44
s = 380.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.1875

Vs2 = 0.00 is calculated for section flange, with:

d = 160.00
Av = 157079.633
fy = 444.44
s = 380.00

Vs2 is multiplied by Col2 = 0.00

s/d = 2.375

Vf ((11-3)-(11.4), ACI 440) = 188111.148

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

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

dfv = d (figure 11.2, ACI 440) = 357.00

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 <= 164661.611

bw = 200.00

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, $\phi = 0.90$

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

Consequently:

Existing material of Primary Member: Concrete Strength, fc = fcm = 15.00

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

Concrete Elasticity, Ec = 18203.022

Steel Elasticity, Es = 200000.00

#####

Note: Especially for the calculation of moment strengths,

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

Existing material: Steel Strength, fs = 1.25*fsm = 555.55

#####

Max Height, Hmax = 400.00

Min Height, Hmin = 200.00

Max Width, Wmax = 400.00

Min Width, Wmin = 200.00

Eccentricity, Ecc = 100.00

Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.27578
Element Length, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 1.5456333E-009$
EDGE -B-
Shear Force, $V_b = -1.5456333E-009$
BOTH EDGES
Axial Force, $F = -4737.328$
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 , $V_e/V_r = 0.55718248$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 126675.449$
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 1.9001E+008$
 $Mu_{1+} = 1.9001E+008$, 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
 $Mu_{1-} = 1.9001E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 1.9001E+008$
 $Mu_{2+} = 1.9001E+008$, 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
 $Mu_{2-} = 1.9001E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.7086748E-005$
 $Mu = 1.9001E+008$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e ((5.4c), TBDY) = a_s e^* s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

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

$$f_x = 0.15303423$$

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

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

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

$$a_f = 0.43111111$$

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

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

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

$$p_{sh,x} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} (\text{Length of stirrups along Y}) = 960.00$$

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

$$A_{\text{sec}} (\text{section area}) = 120000.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} (\text{Length of stirrups along X}) = 960.00$$

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

$$A_{\text{sec}} (\text{section area}) = 120000.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00475778$

$c =$ confinement factor = 1.27578

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

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

$lo/lo_{min} = lb/ld = 0.22053887$

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

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

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

y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

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

$lo/lo_{min} = lb/lb_{min} = 0.22053887$

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

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, ASCE 41-17.

with $fs_2 = fs = 253.4875$

with $Es_2 = Es = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$suv = 0.00365026$

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

$lo/lo_{min} = lb/ld = 0.22053887$

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

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, ASCE 41-17.

with $fsv = fs = 253.4875$

with $Esv = Es = 200000.00$

$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.29147618$

$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.29147618$

$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.6364888$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

$c =$ confinement factor = 1.27578

$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.45459588$

$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.45459588$

$v = Asl_{mid}/(b*d) * (fsv/fc) = 0.99268896$

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

--->

$$s_u(4.8) = 0.40159417$$

$$\mu = M R_c(4.15) = 1.9001E+008$$

$$u = s_u(4.1) = 1.7086748E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

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

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

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

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

$$s = 380.00$$

$$n = 20.00$$

Calculation of μ_1 -

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

$$u = 1.7086748E-005$$

$$\mu = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_c) = 0.018$$

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

$$\text{From (5.4b), TB DY: } \mu = 0.018$$

$$\text{we ((5.4c), TB DY) } = a_s e^* s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

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

$$f_x = 0.15303423$$

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

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

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

$$a_f = 0.43111111$$

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

bmax = 400.00
hmax = 400.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.01016$
bw = 200.00
effective stress from (A.35), $ff,e = 524.0792$

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

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00165347$

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

$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
Lstir (Length of stirrups along Y) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
Lstir (Length of stirrups along X) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

s = 380.00
 $f_{ywe} = 555.55$
fce = 15.00

From ((5.A5), TBDY), TBDY: cc = 0.00475778

c = confinement factor = 1.27578

$y1 = 0.0010562$
 $sh1 = 0.00365026$

$ft1 = 304.185$

$fy1 = 253.4875$

$su1 = 0.00365026$

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

$lo/lo_{,min} = lb/ld = 0.22053887$

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

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

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

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = fs = 253.4875$

with $Es1 = Es = 200000.00$

$y2 = 0.0010562$
 $sh2 = 0.00365026$

$ft2 = 304.185$

$fy2 = 253.4875$

$su2 = 0.00365026$

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

$lo/lo_{,min} = lb/lb_{,min} = 0.22053887$

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

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

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

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = fs = 253.4875$$

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

$$y_v = 0.0010562$$

$$sh_v = 0.00365026$$

$$ft_v = 304.185$$

$$fy_v = 253.4875$$

$$suv = 0.00365026$$

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

$$lo/lo_{u,min} = lb/ld = 0.22053887$$

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

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

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

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $fsv = fs_v/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_v = fs = 253.4875$$

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

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.29147618$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.29147618$$

$$v = Asl_{mid}/(b*d) * (fs_v/fc) = 0.6364888$$

and confined core properties:

$$b = 140.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 19.13667$$

$$cc (5A.5, TBDY) = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.45459588$$

$$2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.45459588$$

$$v = Asl_{mid}/(b*d) * (fs_v/fc) = 0.99268896$$

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

--->

$$su (4.8) = 0.40159417$$

$$Mu = MRc (4.15) = 1.9001E+008$$

$$u = su (4.1) = 1.7086748E-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.22053887$

$$lb = 300.00$$

$$ld = 1360.304$$

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

$$= 1$$

$$db = 18.00$$

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

$fc' = 15.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 24.02082$$

$$Ktr = 0.82673491$$

$$Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$$

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

$$s = 380.00$$

n = 20.00

Calculation of Mu2+

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

$u = 1.7086748E-005$

$Mu = 1.9001E+008$

with full section properties:

b = 200.00

d = 357.00

d' = 43.00

v = 0.00442328

N = 4737.328

$f_c = 15.00$

ϕ_o (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u = \text{shear_factor} * \text{Max}(\phi_u, \phi_o) = 0.018$

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

From (5.4b), TBDY: $\phi_u = 0.018$

ϕ_{we} ((5.4c), TBDY) = $\phi_{ase} * \phi_{sh,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.15303423$

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

$\phi_{fx} = 0.15303423$

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

$\phi_{af} = 0.43111111$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $\phi_{pf} = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

$\phi_{fy} = 0.15303423$

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

$\phi_{af} = 0.43111111$

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

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $\phi_{pf} = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$\phi_{ase} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00165347$

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

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir (\text{Length of stirrups along } Y) = 960.00$$

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

$$Asec (\text{section area}) = 120000.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir (\text{Length of stirrups along } X) = 960.00$$

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

$$Asec (\text{section area}) = 120000.00$$

$$s = 380.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

$$\text{From } ((5.A.5), TBDY), TBDY: cc = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y1 = 0.0010562$$

$$sh1 = 0.00365026$$

$$ft1 = 304.185$$

$$fy1 = 253.4875$$

$$su1 = 0.00365026$$

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

$$lo/lou,min = lb/ld = 0.22053887$$

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

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

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

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = fs = 253.4875$$

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

$$y2 = 0.0010562$$

$$sh2 = 0.00365026$$

$$ft2 = 304.185$$

$$fy2 = 253.4875$$

$$su2 = 0.00365026$$

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

$$lo/lou,min = lb/lb,min = 0.22053887$$

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

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

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

$$y2, sh2,ft2,fy2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = fs = 253.4875$$

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

$$yv = 0.0010562$$

$$shv = 0.00365026$$

$$ftv = 304.185$$

$$fyv = 253.4875$$

$$suv = 0.00365026$$

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

$$lo/lou,min = lb/ld = 0.22053887$$

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

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

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.

$$yv, shv,ftv,fyv, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fsv = fs = 253.4875$$

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.29147618$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.29147618$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$$

and confined core properties:

$$b = 140.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 19.13667$$

$$cc (5A.5, TBDY) = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.45459588$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.45459588$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.99268896$$

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

--->

$$su (4.8) = 0.40159417$$

$$Mu = MRc (4.15) = 1.9001E+008$$

$$u = su (4.1) = 1.7086748E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

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

$$= 1$$

$$d_b = 18.00$$

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

$$f_c' = 15.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

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

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

$$s = 380.00$$

$$n = 20.00$$

Calculation of Mu_2 -

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

$$u = 1.7086748E-005$$

$$Mu = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.018$$

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

$$\text{From (5.4b), TBDY: } cu = 0.018$$

$$\text{we ((5.4c), TBDY) } = ase^* sh, \min * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.15303423$$

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

$$fx = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$
 $a_f = 0.43111111$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 51733.333$

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

$f_y = 0.15303423$

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

$a_f = 0.43111111$

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

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

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

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00475778$

c = confinement factor = 1.27578

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

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

$l_o/l_{ou,min} = l_b/l_d = 0.22053887$

$su_1 = 0.4 * esu_{1,nominal}$ ((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 $f_{sy1} = f_{s1}/1.2$, 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, ASCE 41-17.

with $f_{s1} = f_s = 253.4875$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$

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

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, ASCE 41-17.

with $f_{s2} = f_s = 253.4875$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$su_v = 0.00365026$

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

$l_o/l_{o,min} = l_b/l_d = 0.22053887$

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

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, ASCE 41-17.

with $f_{sv} = f_s = 253.4875$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.29147618$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.29147618$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.6364888$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 19.13667$

$cc (5A.5, TBDY) = 0.00475778$

c = confinement factor = 1.27578

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.45459588$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.45459588$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.99268896$

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

$su (4.8) = 0.40159417$

$Mu = MRc (4.15) = 1.9001E+008$

$u = su (4.1) = 1.7086748E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$

$l_d = 1360.304$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

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

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

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

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

$$s = 380.00$$

$$n = 20.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227350.021$

Calculation of Shear Strength at edge 1, $V_{r1} = 227350.021$

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

$$V_{Col0} = 227350.021$$

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

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

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

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu_u = 0.00988804$$

$$V_u = 1.5456333E-009$$

$$d = 0.8 * h = 320.00$$

$$N_u = 4737.328$$

$$A_g = 80000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 0.00$$

where:

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

$$d = 160.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

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

$$s/d = 2.375$$

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

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

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

$$s/d = 1.1875$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 188111.148$$

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

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

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

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

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

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

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 357.00$$

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

$$E_f = 64828.00$$

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

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

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$
 $bw = 200.00$

Calculation of Shear Strength at edge 2, $V_r2 = 227350.021$
 $V_r2 = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 227350.021$
 $knl = 1$ (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)
 $fc' = 15.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.00525978$

$V_u = 1.5456333E-009$

$d = 0.8 * h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

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

$s/d = 2.375$

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

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

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

$s/d = 1.1875$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

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

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

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

orientation 1: $a_1 = b1 + 90^\circ = 90.00$

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

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

$dfv = d$ (figure 11.2, ACI 440) = 357.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$

$bw = 200.00$

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, $\phi = 0.90$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
 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, $f_c = f_{cm} = 15.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 18203.022$
 Steel Elasticity, $E_s = 200000.00$
 Max Height, $H_{max} = 400.00$
 Min Height, $H_{min} = 200.00$
 Max Width, $W_{max} = 400.00$
 Min Width, $W_{min} = 200.00$
 Eccentricity, $Ecc = 100.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i = 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 47.67334$
 Shear Force, $V_2 = -2811.342$
 Shear Force, $V_3 = -0.02136663$
 Axial Force, $F = -4735.965$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{st} = 2375.044$
 -Compression: $A_{sc} = 2777.168$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{st,ten} = 2261.947$
 -Compression: $A_{st,com} = 829.3805$
 -Middle: $A_{st,mid} = 2060.885$
 Mean Diameter of Tension Reinforcement, $D_bL = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \phi \cdot u = 0.01664493$
 $u = y + p = 0.01849436$

- Calculation of y -

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.01849436$ ((4.29), Biskinis Phd)
 $M_y = 1.9917E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 2231.206
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 8.0093E+012$
 factor = 0.30
 $A_g = 120000.00$
 $f_c' = 15.00$
 $N = 4735.965$

$$E_c \cdot I_g = 2.6698E+013$$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 400.00$

web width, $b_w = 200.00$

flange thickness, $t = 200.00$

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

$$y_{\text{ten}} = 5.8877816E-006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 235.317$$

$$d = 357.00$$

$$y = 0.44023806$$

$$A = 0.03622085$$

$$B = 0.0247656$$

$$\text{with } p_t = 0.0075814$$

$$p_c = 0.00580799$$

$$p_v = 0.01443197$$

$$N = 4735.965$$

$$b = 400.00$$

$$" = 0.12044818$$

$$y_{\text{comp}} = 1.0200777E-005$$

$$\text{with } f_c^* (12.3, (\text{ACI 440})) = 16.19674$$

$$f_c = 15.00$$

$$f_l = 0.93147527$$

$$b = b_{\text{max}} = 400.00$$

$$h = h_{\text{max}} = 400.00$$

$$A_g = 120000.00$$

$$g = p_t + p_c + p_v = 0.03607992$$

$$r_c = 40.00$$

$$A_e/A_c = 0.40981737$$

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

$$\text{effective strain from } (12.5) \text{ and } (12.12), \text{efe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 18203.022$$

$$y = 0.43979991$$

$$A = 0.03597638$$

$$B = 0.02462466$$

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

CONFIRMATION: $y = 0.43979991 < t/d$

Calculation of ratio l_b/d

$$\text{Lap Length: } l_d/l_d, \text{min} = 0.27567359$$

$$l_b = 300.00$$

$$l_d = 1088.244$$

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

$$= 1$$

$$d_b = 18.00$$

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

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

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

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

$$s = 380.00$$

n = 20.00

- Calculation of ρ -

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

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$
shear control ratio $V_y E / V_{CoI} E = 0.82694402$

d = 357.00

s = 0.00

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.0075814$

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

$L_{stir} = 960.00$, 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 = 4735.965

$A_g = 120000.00$

$f_{cE} = 15.00$

$f_{ytE} = f_{ylE} = 444.44$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.03607992$

b = 400.00

d = 357.00

$f_{cE} = 15.00$

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

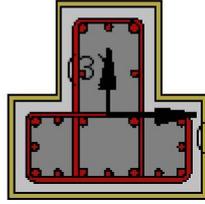
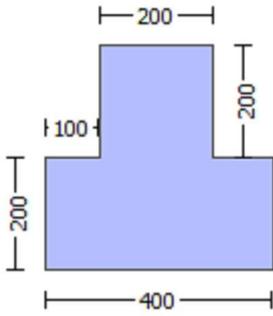
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

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, $f_c = f_{c_lower_bound} = 10.00$

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

Concrete Elasticity, $E_c = 18203.022$

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$

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

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = 47.67334$

Shear Force, $V_a = -0.02136663$
EDGE -B-
Bending Moment, $M_b = 21.03175$
Shear Force, $V_b = 0.02136663$
BOTH EDGES
Axial Force, $F = -4735.965$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 2375.044$
-Compression: $A_{sc} = 2777.168$
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 $V_R = \phi V_n = 144111.087$
 V_n ((10.3), ASCE 41-17) = $k_n V_{CoIO} = 160123.429$
 $V_{CoI} = 160123.429$
 $k_n = 1.00$
displacement_ductility_demand = $1.7523658E-005$

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)
 $f_c' = 10.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 47.67334$
 $V_u = 0.02136663$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 4735.965$
 $A_g = 80000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$
where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.1875$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 2.375$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, 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) = 357.00
 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: $V_s + V_f \leq 134445.642$

bw = 200.00

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 = 3.2408892E-007
 $y = (M_y * L_s / 3) / E_{eff} = 0.01849436$ ((4.29), Biskinis Phd))
 $M_y = 1.9917E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2231.206
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 8.0093E+012$
factor = 0.30
 $A_g = 120000.00$
 $f_c' = 15.00$
 $N = 4735.965$
 $E_c * I_g = 2.6698E+013$

Calculation of Yielding Moment M_y

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

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:
flange width, $b = 400.00$
web width, $bw = 200.00$
flange thickness, $t = 200.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 5.8877816E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 235.317$
 $d = 357.00$
 $y = 0.44023806$
 $A = 0.03622085$
 $B = 0.0247656$
with $pt = 0.01583996$
 $pc = 0.00580799$
 $pv = 0.01443197$
 $N = 4735.965$
 $b = 400.00$
 $\lambda = 0.12044818$
 $y_{comp} = 1.0200777E-005$
with $f_c' (12.3, (ACI 440)) = 16.19674$
 $f_c = 15.00$
 $f_l = 0.93147527$
 $b = b_{max} = 400.00$
 $h = h_{max} = 400.00$
 $A_g = 120000.00$
 $g = pt + pc + pv = 0.03607992$
 $rc = 40.00$
 $A_e / A_c = 0.40981737$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 18203.022$
 $y = 0.43979991$
 $A = 0.03597638$
 $B = 0.02462466$
with $E_s = 200000.00$
CONFIRMATION: $y = 0.43979991 < t/d$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.27567359$

$l_b = 300.00$

$l_d = 1088.244$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$

$d_b = 18.00$

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

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 24.02082$

$K_{tr} = 0.82673491$

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

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

$s = 380.00$

$n = 20.00$

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

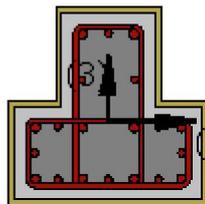
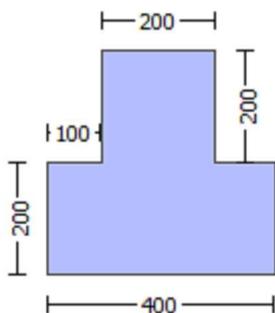
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

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, $\phi = 0.90$

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

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

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

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.27578

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.01054019$

EDGE -B-

Shear Force, $V_b = -0.01054019$

BOTH EDGES

Axial Force, $F = -4737.328$

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, $V_e/V_r = 0.82694402$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 162085.836$
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.4313E+008$

Mu1+ = 2.4313E+008, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

Mu1- = 1.2706E+008, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

Mpr2 = Max(Mu2+ , Mu2-) = 2.4313E+008

Mu2+ = 2.4313E+008, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

Mu2- = 1.2706E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

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

$$\kappa_u = 2.6161250E-005$$

$$M_u = 2.4313E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

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

$$\text{Final value of } \kappa_u: \kappa_u^* = \text{shear_factor} * \text{Max}(\kappa_u, \kappa_c) = 0.018$$

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

$$\text{From (5.4b), TBDY: } \kappa_u = 0.018$$

$$\kappa_{ue} \text{ ((5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(\kappa_{fx}, \kappa_{fy}) = 0.15303423$$

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

$$\kappa_{fx} = 0.15303423$$

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

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$\kappa_{fy} = 0.15303423$$

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

$$a_f = 0.43111111$$

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

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and

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

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

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

 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

$c = \text{confinement factor} = 1.27578$

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

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

$lo/lo_{min} = lb/ld = 0.22053887$

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

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

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

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

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

$lo/lo_{min} = lb/lb_{min} = 0.22053887$

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

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

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

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = fs = 253.4875$

with $Es_2 = Es = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$su_v = 0.00365026$

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

$lo/lo_{min} = lb/ld = 0.22053887$

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

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

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

For calculation of $esu_{v_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

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

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = f_s = 253.4875$

with $E_{sv} = E_s = 200000.00$

1 = $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.53536441$

2 = $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.19630028$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.48777647$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 19.13667$

$cc (5A.5, TBDY) = 0.00475778$

$c = \text{confinement factor} = 1.27578$

1 = $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.83497202$

2 = $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.30615641$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.76075229$

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

---->

$c_u (4.10) = 0.46564051$

$M_{Rc} (4.17) = 2.0934E+008$

---->

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

---->

$*c_u (4.10) = 0.55615794$

$M_{Ro} (4.17) = 2.4313E+008$

---->

$u = c_u (4.2) = 2.6161250E-005$

$\mu = M_{Ro}$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$

Id = 1360.304

Calculation of $I_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

db = 18.00

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

$f_c' = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

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

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

s = 380.00

n = 20.00

Calculation of μ_1 -

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

$\mu = 1.3353763E-005$

$\mu_1 = 1.2706E+008$

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00221164

N = 4737.328

$f_c = 15.00$

α (5A.5, TBDY) = 0.002

Final value of μ_1 : $\mu_1^* = \text{shear_factor} * \text{Max}(\mu_1, \mu_c) = 0.018$

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

From (5.4b), TBDY: $\mu_1 = 0.018$

where $\mu_1^* = \alpha * \text{sh}_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

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

 $f_x = 0.15303423$

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

$\alpha_f = 0.43111111$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

$f_y = 0.15303423$

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

$\alpha_f = 0.43111111$

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

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

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

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

$c = \text{confinement factor} = 1.27578$

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

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

$lo/lo_{u,min} = lb/ld = 0.22053887$

$su_1 = 0.4 * esu1_{nominal}$ ((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, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

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

$lo/lo_{u,min} = lb/lb_{min} = 0.22053887$

$su_2 = 0.4 * esu2_{nominal}$ ((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, ASCE 41-17.

with $fs_2 = fs = 253.4875$

with $Es_2 = Es = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$su_v = 0.00365026$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lo_{u,min} = lb/ld = 0.22053887

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

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

considering characteristic value fs_{yv} = fsv/1.2, from table 5.1, TBDY

For calculation of esuv_nominal and γ_v, sh_v,ft_v,fy_v, it is considered characteristic value fs_{yv} = fsv/1.2, from table 5.1, TBDY.

γ₁, sh₁,ft₁,fy₁, are also multiplied by Min(1,1.25*(lb/ld)^{2/3}), from 10.3.5, ASCE 41-17.

with fsv = fs = 253.4875

with Esv = Es = 200000.00

1 = Asl_{ten}/(b*d)*(fs₁/fc) = 0.09815014

2 = Asl_{com}/(b*d)*(fs₂/fc) = 0.26768221

v = Asl_{mid}/(b*d)*(fsv/fc) = 0.24388823

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

c = confinement factor = 1.27578

1 = Asl_{ten}/(b*d)*(fs₁/fc) = 0.1260644

2 = Asl_{com}/(b*d)*(fs₂/fc) = 0.34381201

v = Asl_{mid}/(b*d)*(fsv/fc) = 0.31325094

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

su (4.9) = 0.23431248

Mu = MRc (4.14) = 1.2706E+008

u = su (4.1) = 1.3353763E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.22053887

lb = 300.00

ld = 1360.304

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

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 15.00, but fc^{0.5} <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

Atr = Min(Atr_x,Atr_y) = 157.0796

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

s = 380.00

n = 20.00

Calculation of Mu2+

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

u = 2.6161250E-005

Mu = 2.4313E+008

with full section properties:

b = 200.00

d = 357.00

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e(5.4c, TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

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

$$f_x = 0.15303423$$

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

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$f_y = 0.15303423$$

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

$$a_f = 0.43111111$$

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

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

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

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 960.00$$

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

$$A_{sec} \text{ (section area)} = 120000.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} \text{ (Length of stirrups along X)} = 960.00$$

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

$$A_{sec} \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$y1 = 0.0010562$
 $sh1 = 0.00365026$
 $ft1 = 304.185$
 $fy1 = 253.4875$
 $su1 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/d = 0.22053887$
 $su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fs1 = fs = 253.4875$
 with $Es1 = Es = 200000.00$

$y2 = 0.0010562$
 $sh2 = 0.00365026$
 $ft2 = 304.185$
 $fy2 = 253.4875$
 $su2 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.22053887$
 $su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2,ft2,fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs2 = fs = 253.4875$
 with $Es2 = Es = 200000.00$

$yv = 0.0010562$
 $shv = 0.00365026$
 $ftv = 304.185$
 $fyv = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/d = 0.22053887$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $Esv = Es = 200000.00$

$1 = Asl,ten/(b*d)*(fs1/fc) = 0.53536441$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.19630028$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.48777647$

and confined core properties:

$b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.83497202$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.30615641$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.76075229$

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

--->
 $v < vs,y2$ - 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

---->

ϕ_{cu} (4.10) = 0.46564051

MRC (4.17) = 2.0934E+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} , ϕ_{cc} , used in lieu of f_c , ϕ_{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

---->

ϕ^*_{cu} (4.10) = 0.55615794

MRO (4.17) = 2.4313E+008

---->

$u = \phi_{cu}$ (4.2) = 2.6161250E-005

$\mu = MRO$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$

$l_d = 1360.304$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 18.00$

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

$f'_c = 15.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 24.02082$

$K_{tr} = 0.82673491$

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

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

$s = 380.00$

$n = 20.00$

Calculation of μ_2 -

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

$$u = 1.3353763E-005$$

$$\mu = 1.2706E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00221164$$

$$N = 4737.328$$

$$f_c = 15.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.018$$

$$\omega_e (5.4c, \text{TBDY}) = a_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.15303423$$

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

$$\phi_x = 0.15303423$$

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

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$\phi_y = 0.15303423$$

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

$$a_f = 0.43111111$$

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

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00165347$$

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

$$\text{psh}_x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 960.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 120000.00$$

$$\text{psh}_y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 960.00$$

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

Asec (section area) = 120000.00

s = 380.00

fywe = 555.55

fce = 15.00

From ((5.A.5), TBDY), TBDY: cc = 0.00475778

c = confinement factor = 1.27578

y1 = 0.0010562

sh1 = 0.00365026

ft1 = 304.185

fy1 = 253.4875

su1 = 0.00365026

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

lo/lou,min = lb/ld = 0.22053887

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE 41-17.

with fs1 = fs = 253.4875

with Es1 = Es = 200000.00

y2 = 0.0010562

sh2 = 0.00365026

ft2 = 304.185

fy2 = 253.4875

su2 = 0.00365026

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

lo/lou,min = lb/lb,min = 0.22053887

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE 41-17.

with fs2 = fs = 253.4875

with Es2 = Es = 200000.00

yv = 0.0010562

shv = 0.00365026

ftv = 304.185

fyv = 253.4875

suv = 0.00365026

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

lo/lou,min = lb/ld = 0.22053887

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE 41-17.

with fsv = fs = 253.4875

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09815014

2 = Asl,com/(b*d)*(fs2/fc) = 0.26768221

v = Asl,mid/(b*d)*(fsv/fc) = 0.24388823

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

c = confinement factor = 1.27578

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1260644

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.34381201$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.31325094$$

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

---->

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

---->

$$s_u(4.9) = 0.23431248$$

$$M_u = M_{Rc}(4.14) = 1.2706E+008$$

$$u = s_u(4.1) = 1.3353763E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

$$d_b = 18.00$$

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

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

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

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

$$s = 380.00$$

$$n = 20.00$$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 196005.816$

Calculation of Shear Strength at edge 1, $V_{r1} = 227350.021$

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

$$V_{Col0} = 227350.021$$

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

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)

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 3.21769$$

$$V_u = 0.01054019$$

$$d = 0.8*h = 320.00$$

$$N_u = 4737.328$$

$$A_g = 80000.00$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

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

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

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

$$s/d = 1.1875$$

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

$$d = 160.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

Vs2 is multiplied by Col2 = 0.00

$$s/d = 2.375$$

$$V_f((11-3)-(11.4), \text{ACI 440}) = 188111.148$$

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

$$dfv = d \text{ (figure 11.2, ACI 440)} = 357.00$$

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 164661.611$$

$$bw = 200.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 196005.816$

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

$$V_{Col0} = 196005.816$$

kn1 = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

$$f_c' = 15.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 23.99609$$

$$V_u = 0.01054019$$

$$d = 0.8 * h = 320.00$$

$$N_u = 4737.328$$

$$A_g = 80000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 0.00$$

where:

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

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s1} is multiplied by Col1 = 0.00

$$s/d = 1.1875$$

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

$$d = 160.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s2} is multiplied by Col2 = 0.00

$$s/d = 2.375$$

$$V_f((11-3)-(11.4), \text{ACI 440}) = 188111.148$$

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

$$dfv = d \text{ (figure 11.2, ACI 440)} = 357.00$$

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 164661.611$
 $bw = 200.00$

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, $\phi = 0.90$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 15.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 18203.022$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

Max Height, $H_{max} = 400.00$
Min Height, $H_{min} = 200.00$
Max Width, $W_{max} = 400.00$
Min Width, $W_{min} = 200.00$
Eccentricity, $Ecc = 100.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.27578
Element Length, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 1.5456333E-009$
EDGE -B-
Shear Force, $V_b = -1.5456333E-009$
BOTH EDGES
Axial Force, $F = -4737.328$
Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: Asl,t = 0.00

-Compression: Asl,c = 5152.212

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,t_{ten} = 1231.504

-Compression: Asl,c_{com} = 1231.504

-Middle: Asl,mid = 2689.203

Calculation of Shear Capacity ratio , $V_e/V_r = 0.55718248$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 126675.449$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.9001E+008$

$M_{u1+} = 1.9001E+008$, 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

$M_{u1-} = 1.9001E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.9001E+008$

$M_{u2+} = 1.9001E+008$, 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

$M_{u2-} = 1.9001E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

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

$\phi_u = 1.7086748E-005$

$M_u = 1.9001E+008$

with full section properties:

$b = 200.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00442328$

$N = 4737.328$

$f_c = 15.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$

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

From (5.4b), TBDY: $\phi_u = 0.018$

ϕ_{ve} ((5.4c), TBDY) = $a_{se} * \phi_{sh,min} * f_{yve}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.15303423$

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

$\phi_x = 0.15303423$

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

$a_f = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $\phi_{pf} = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

$\phi_y = 0.15303423$

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

$a_f = 0.43111111$

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

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $\phi_{pf} = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

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

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

c = confinement factor = 1.27578

$y1 = 0.0010562$

$sh1 = 0.00365026$

$ft1 = 304.185$

$fy1 = 253.4875$

$su1 = 0.00365026$

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

$l_o/l_{o,min} = l_b/l_d = 0.22053887$

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

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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = fs = 253.4875$

with $Es1 = Es = 200000.00$

$y2 = 0.0010562$

$sh2 = 0.00365026$

$ft2 = 304.185$

$fy2 = 253.4875$

$su2 = 0.00365026$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$

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

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 $fsy2 = fs2/1.2$, 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, ASCE 41-17.

with $f_{s2} = f_s = 253.4875$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0010562$
 $sh_v = 0.00365026$
 $ft_v = 304.185$
 $fy_v = 253.4875$
 $su_v = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.22053887$
 $su_v = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{sv} = f_s = 253.4875$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.29147618$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.29147618$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.6364888$
 and confined core properties:
 $b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = A_{sl,ten}/(b*d) * (f_{s1}/f_c) = 0.45459588$
 $2 = A_{sl,com}/(b*d) * (f_{s2}/f_c) = 0.45459588$
 $v = A_{sl,mid}/(b*d) * (f_{sv}/f_c) = 0.99268896$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$
 $l_b = 300.00$
 $l_d = 1360.304$
 Calculation of l_b,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f'_c = 15.00$, but $f'_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 24.02082$
 $K_{tr} = 0.82673491$
 $A_{tr} = Min(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 380.00$
 $n = 20.00$

 Calculation of μ_1 -

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

$$\mu = 1.7086748E-005$$

$$\mu_u = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.018$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.018$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = \alpha s_e * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

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

$$f_x = 0.15303423$$

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

$$\alpha_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 51733.333$$

$$b_{\text{max}} = 400.00$$

$$h_{\text{max}} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$f_y = 0.15303423$$

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

$$\alpha_f = 0.43111111$$

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

$$b_{\text{max}} = 400.00$$

$$h_{\text{max}} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

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

$$f_u, f = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh, \text{min}} = \text{Min}(p_{sh, x}, p_{sh, y}) = 0.00165347$$

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

$$p_{sh, x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 960.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 120000.00$$

$$\text{psh,y ((5.4d), TBDY)} = \text{Lstir} \cdot \text{Astir} / (\text{Asec} \cdot \text{s}) = 0.00165347$$

$$\text{Lstir (Length of stirrups along X)} = 960.00$$

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

$$\text{Asec (section area)} = 120000.00$$

$$\text{s} = 380.00$$

$$\text{fywe} = 555.55$$

$$\text{fce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: cc} = 0.00475778$$

$$\text{c} = \text{confinement factor} = 1.27578$$

$$\text{y1} = 0.0010562$$

$$\text{sh1} = 0.00365026$$

$$\text{ft1} = 304.185$$

$$\text{fy1} = 253.4875$$

$$\text{su1} = 0.00365026$$

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

$$\text{lo/lou,min} = \text{lb/l_d} = 0.22053887$$

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

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, ASCE 41-17.

$$\text{with fs1} = \text{fs} = 253.4875$$

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

$$\text{y2} = 0.0010562$$

$$\text{sh2} = 0.00365026$$

$$\text{ft2} = 304.185$$

$$\text{fy2} = 253.4875$$

$$\text{su2} = 0.00365026$$

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

$$\text{lo/lou,min} = \text{lb/l_b,min} = 0.22053887$$

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

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, ASCE 41-17.

$$\text{with fs2} = \text{fs} = 253.4875$$

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

$$\text{yv} = 0.0010562$$

$$\text{shv} = 0.00365026$$

$$\text{ftv} = 304.185$$

$$\text{fyv} = 253.4875$$

$$\text{suv} = 0.00365026$$

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

$$\text{lo/lou,min} = \text{lb/l_d} = 0.22053887$$

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

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 $\text{Min}(1, 1.25 \cdot (\text{lb/l_d})^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with fsv} = \text{fs} = 253.4875$$

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

$$1 = \text{Asl,ten} / (\text{b} \cdot \text{d}) \cdot (\text{fs1} / \text{fc}) = 0.29147618$$

$$2 = \text{Asl,com} / (\text{b} \cdot \text{d}) \cdot (\text{fs2} / \text{fc}) = 0.29147618$$

$$\text{v} = \text{Asl,mid} / (\text{b} \cdot \text{d}) \cdot (\text{fsv} / \text{fc}) = 0.6364888$$

and confined core properties:

$$\text{b} = 140.00$$

$$\text{d} = 327.00$$

$$\text{d}' = 13.00$$

$$\text{fcc (5A.2, TBDY)} = 19.13667$$

$$cc \text{ (5A.5, TBDY)} = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$1 = Asl_{ten}/(b*d)*(fs1/fc) = 0.45459588$$

$$2 = Asl_{com}/(b*d)*(fs2/fc) = 0.45459588$$

$$v = Asl_{mid}/(b*d)*(fsv/fc) = 0.99268896$$

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

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

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

$$su \text{ (4.8)} = 0.40159417$$

$$Mu = MRc \text{ (4.15)} = 1.9001E+008$$

$$u = su \text{ (4.1)} = 1.7086748E-005$$

Calculation of ratio l_b/l_d

$$\text{Lap Length: } l_b/l_d = 0.22053887$$

$$l_b = 300.00$$

$$l_d = 1360.304$$

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

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 555.55$$

$$f'_c = 15.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

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

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

$$s = 380.00$$

$$n = 20.00$$

Calculation of Mu_{2+}

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

$$u = 1.7086748E-005$$

$$Mu = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f'_c = 15.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.018$$

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

$$\text{From (5.4b), TBDY: } cu = 0.018$$

$$\text{we ((5.4c), TBDY) } = ase * sh_{min} * f_{ywe}/f_{ce} + \text{Min}(fx, fy) = 0.15303423$$

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

$$fx = 0.15303423$$

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

$$af = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.01016$
 $bw = 200.00$
effective stress from (A.35), $ff,e = 524.0792$

$fy = 0.15303423$

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

$af = 0.43111111$

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

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $ff,e = 524.0792$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

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

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

$c = \text{confinement factor} = 1.27578$

$y1 = 0.0010562$

$sh1 = 0.00365026$

$ft1 = 304.185$

$fy1 = 253.4875$

$su1 = 0.00365026$

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

$lo/lo_{u,min} = lb/ld = 0.22053887$

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

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, ASCE 41-17.

with $fs1 = fs = 253.4875$

with $Es1 = Es = 200000.00$

$y2 = 0.0010562$

$sh_2 = 0.00365026$
 $ft_2 = 304.185$
 $fy_2 = 253.4875$
 $su_2 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/lb_{u,min} = 0.22053887$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fs_2 = fs = 253.4875$
 with $Es_2 = Es = 200000.00$
 $yv = 0.0010562$
 $shv = 0.00365026$
 $ftv = 304.185$
 $fyv = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.22053887$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.29147618$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.29147618$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.6364888$
 and confined core properties:
 $b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.45459588$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.45459588$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.99268896$
 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
 --->
 $su (4.8) = 0.40159417$
 $Mu = MRc (4.15) = 1.9001E+008$
 $u = su (4.1) = 1.7086748E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.22053887$
 $lb = 300.00$
 $ld = 1360.304$
 Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 15.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00
s = 0.80
e = 1.00
cb = 24.02082
Ktr = 0.82673491
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis
s = 380.00
n = 20.00

Calculation of Mu2-

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

u = 1.7086748E-005
Mu = 1.9001E+008

with full section properties:

b = 200.00
d = 357.00
d' = 43.00
v = 0.00442328
N = 4737.328
fc = 15.00
co (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.018$
 ϕ_{ue} ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.15303423$
where $\phi = \text{af} * \text{pf} * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.15303423$

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

$\text{af} = 0.43111111$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

 $\phi_y = 0.15303423$

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

$\text{af} = 0.43111111$

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

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\text{ase} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core 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 = 0.00 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 = 33066.667 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) = 0.00165347

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

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00165347

Lstir (Length of stirrups along Y) = 960.00

Astir (stirrups area) = 78.53982

Asec (section area) = 120000.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00165347

Lstir (Length of stirrups along X) = 960.00

Astir (stirrups area) = 78.53982

Asec (section area) = 120000.00

s = 380.00

fywe = 555.55

fce = 15.00

From ((5.A5), TBDY), TBDY: cc = 0.00475778

c = confinement factor = 1.27578

y1 = 0.0010562

sh1 = 0.00365026

ft1 = 304.185

fy1 = 253.4875

su1 = 0.00365026

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

lo/lou,min = lb/l_d = 0.22053887

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

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

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

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs1 = fs = 253.4875

with Es1 = Es = 200000.00

y2 = 0.0010562

sh2 = 0.00365026

ft2 = 304.185

fy2 = 253.4875

su2 = 0.00365026

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

lo/lou,min = lb/l_b,min = 0.22053887

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

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

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

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs2 = fs = 253.4875

with Es2 = Es = 200000.00

yv = 0.0010562

shv = 0.00365026

ftv = 304.185

fyv = 253.4875

suv = 0.00365026

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

lo/lou,min = lb/l_d = 0.22053887

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 $e_{sv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = f_s = 253.4875$

with $E_{sv} = E_s = 200000.00$

1 = $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.29147618$

2 = $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.29147618$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.6364888$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

c = confinement factor = 1.27578

1 = $A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.45459588$

2 = $A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.45459588$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.99268896$

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) = 0.40159417

$Mu = MRc$ (4.15) = 1.9001E+008

$u = su$ (4.1) = 1.7086748E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$

$l_d = 1360.304$

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

= 1

$db = 18.00$

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

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 24.02082$

$K_{tr} = 0.82673491$

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

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

$s = 380.00$

$n = 20.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227350.021$

Calculation of Shear Strength at edge 1, $V_{r1} = 227350.021$

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

$V_{Col0} = 227350.021$

$k_{nl} = 1$ (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)

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 0.00988804$

$V_u = 1.5456333E-009$
 $d = 0.8 \cdot h = 320.00$
 $Nu = 4737.328$
 $Ag = 80000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$
where:

$V_{s1} = 0.00$ is calculated for section web, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 2.375$

$V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.1875$

V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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: $V_s + V_f \leq 164661.611$

$bw = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 227350.021$

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

$V_{Col0} = 227350.021$

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

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

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

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.00525978$

$V_u = 1.5456333E-009$

$d = 0.8 \cdot h = 320.00$

$Nu = 4737.328$

$Ag = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

$V_{s1} = 0.00$ is calculated for section web, with:
 $d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

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

$s/d = 2.375$

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

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

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

$s/d = 1.1875$

$V_f((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$

$b_w = 200.00$

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, $\gamma = 0.90$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

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, $f_c = f_{cm} = 15.00$

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

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $E_{cc} = 100.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -8.4385E+006$

Shear Force, $V2 = -2811.342$

Shear Force, $V3 = -0.02136663$

Axial Force, $F = -4735.965$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 2375.044$

-Compression: $As_c = 2777.168$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{,ten} = 1231.504$

-Compression: $As_{,com} = 1231.504$

-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 $u_{,R} = u = 0.01876684$

$u = y + p = 0.02085204$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.02085204$ ((4.29), Biskinis Phd)

$M_y = 1.3657E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3001.586

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 6.5531E+012$

factor = 0.30

$A_g = 120000.00$

$f_c' = 15.00$

$N = 4735.965$

$E_c * I_g = 2.1844E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{,ten} = 5.8874222E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 235.317$

$d = 357.00$

$y = 0.44020389$

$A = 0.07244171$

$B = 0.04070755$

with $pt = 0.0075814$

$pc = 0.01724796$

$pv = 0.03766391$

$N = 4735.965$

$b = 200.00$

$r = 0.12044818$

$y_{,comp} = 1.0162905E-005$

with $f_c' (12.3, (ACI 440)) = 16.12972$

$f_c = 15.00$

$f_l = 0.93147527$

$b = b_{max} = 400.00$

$h = h_{max} = 400.00$

$A_g = 120000.00$

$g = pt + pc + pv = 0.07215983$

$rc = 40.00$

$A_e / A_c = 0.38686758$

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

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 18203.022$
 $y = 0.43961224$
 $A = 0.0719519$
 $B = 0.04042568$
with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.27567359$
 $l_b = 300.00$
 $l_d = 1088.244$

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

$= 1$

$d_b = 18.00$

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

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 24.02082$

$K_{tr} = 0.82673491$

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

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

$s = 380.00$

$n = 20.00$

- Calculation of ρ -

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

with:

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

shear control ratio $V_y E / V_{col} O E = 0.55718248$

$d = 357.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.0075814$

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

$L_{stir} = 960.00$, 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.

$NUD = 4735.965$

$A_g = 120000.00$

$f_{cE} = 15.00$

$f_{yE} = f_{yI} = 444.44$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.07215983$

$b = 200.00$

$d = 357.00$

$f_{cE} = 15.00$

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

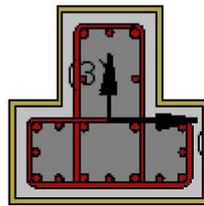
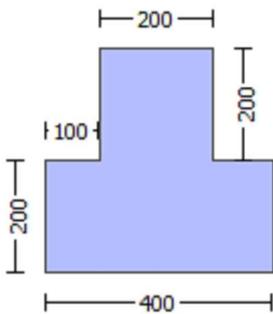
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



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

At local axis: 2

Integration Section: (b)

Section Type: rctcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

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, $f_c = f_{c_lower_bound} = 10.00$

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

Concrete Elasticity, $E_c = 18203.022$

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$

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

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -8.4385E+006$
Shear Force, $V_a = -2811.342$
EDGE -B-
Bending Moment, $M_b = -136.3192$
Shear Force, $V_b = 2811.342$
BOTH EDGES
Axial Force, $F = -4735.965$
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, $D_{bL,ten} = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = *V_n = 167221.095$
 $V_n ((10.3), ASCE 41-17) = k_{nl} * V_{CoI0} = 185801.217$
 $V_{CoI} = 185801.217$
 $k_{nl} = 1.00$
 $displacement_ductility_demand = 0.09266918$

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)
 $f_c' = 10.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 136.3192$
 $V_u = 2811.342$
 $d = 0.8 * h = 320.00$
 $N_u = 4735.965$
 $A_g = 80000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$
where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 2.375$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 320.00$
 $A_v = 157079.633$

$f_y = 400.00$
 $s = 380.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.1875$
 $V_f((11-3)-(11.4), ACI 440) = 188111.148$
 $f = 0.95$, 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) = 357.00
 $f_{fe}((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 134445.642$
 $b_w = 200.00$

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 $\theta = 0.00019313$
 $y = (M_y * L_s / 3) / E_{eff} = 0.0020841$ ((4.29), Biskinis Phd))
 $M_y = 1.3657E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 6.5531E+012$
 $\text{factor} = 0.30$
 $A_g = 120000.00$
 $f_c' = 15.00$
 $N = 4735.965$
 $E_c * I_g = 2.1844E+013$

Calculation of Yielding Moment M_y

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

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 5.8874222E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 235.317$
 $d = 357.00$
 $y = 0.44020389$
 $A = 0.07244171$
 $B = 0.04070755$
 with $p_t = 0.01724796$
 $p_c = 0.01724796$
 $p_v = 0.03766391$
 $N = 4735.965$
 $b = 200.00$
 $\theta = 0.12044818$
 $y_{comp} = 1.0162905E-005$
 with $f_c'((12.3, (ACI 440))) = 16.12972$
 $f_c = 15.00$
 $f_l = 0.93147527$
 $b = b_{max} = 400.00$
 $h = h_{max} = 400.00$
 $A_g = 120000.00$
 $g = p_t + p_c + p_v = 0.07215983$

rc = 40.00
Ae/Ac = 0.38686758
Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
Ef = 64828.00
Ec = 18203.022
y = 0.43961224
A = 0.0719519
B = 0.04042568
with Es = 200000.00

Calculation of ratio l_b/d

Lap Length: $l_b/d_{\min} = 0.27567359$

$l_b = 300.00$

$l_d = 1088.244$

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

= 1

$d_b = 18.00$

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

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

$K_{tr} = 0.82673491$

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

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

s = 380.00

n = 20.00

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

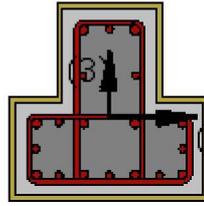
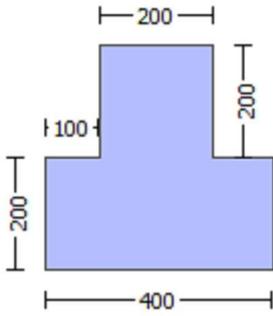
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: End

Local Axis: (2)



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

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

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

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

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.27578

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.01054019$

EDGE -B-

Shear Force, $V_b = -0.01054019$
BOTH EDGES
Axial Force, $F = -4737.328$
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, $V_e/V_r = 0.82694402$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 162085.836$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.4313E+008$
 $\mu_{u1+} = 2.4313E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $\mu_{u1-} = 1.2706E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.4313E+008$
 $\mu_{u2+} = 2.4313E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination
 $\mu_{u2-} = 1.2706E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 2.6161250E-005$
 $M_u = 2.4313E+008$

with full section properties:

$b = 200.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00442328$
 $N = 4737.328$

$f_c = 15.00$

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

Final value of μ_{cu} : $\mu_{cu}^* = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.018$

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

From (5.4b), TBDY: $\mu_{cu} = 0.018$

where $\mu_{cu} = \alpha_{co} * \mu_{cu}^* = \alpha_{co} * \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.15303423$

where $\mu_{cu} = \alpha_{co} * \mu_{cu}^* = \alpha_{co} * \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.15303423$

 $\mu_{cu} = 0.15303423$

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

$\alpha_{af} = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $\mu_{pf} = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

 $\mu_{cy} = 0.15303423$

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

$\alpha_{af} = 0.43111111$

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

$b_{max} = 400.00$

hmax = 400.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.01016$
bw = 200.00
effective stress from (A.35), $ff,e = 524.0792$

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

$ase = \text{Max}((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}} * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

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

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$
 L_{stir} (Length of stirrups along Y) = 960.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 120000.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$
 L_{stir} (Length of stirrups along X) = 960.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 120000.00

s = 380.00

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

c = confinement factor = 1.27578

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

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

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.22053887$

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

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, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

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

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$

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

From table 5A.1, TBDY: $esu2_nominal = 0.08$,
For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $fs2 = fs = 253.4875$
with $Es2 = Es = 200000.00$
 $yv = 0.0010562$
 $shv = 0.00365026$
 $ftv = 304.185$
 $fyv = 253.4875$
 $suv = 0.00365026$
using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$
and also multiplied by the $shear_factor$ according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou, min = lb/d = 0.22053887$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
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, ASCE 41-17.
with $fsv = fs = 253.4875$
with $Es = Es = 200000.00$
 $1 = Asl, ten/(b*d)*(fs1/fc) = 0.53536441$
 $2 = Asl, com/(b*d)*(fs2/fc) = 0.19630028$
 $v = Asl, mid/(b*d)*(fsv/fc) = 0.48777647$
and confined core properties:
 $b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = confinement\ factor = 1.27578$
 $1 = Asl, ten/(b*d)*(fs1/fc) = 0.83497202$
 $2 = Asl, com/(b*d)*(fs2/fc) = 0.30615641$
 $v = Asl, mid/(b*d)*(fsv/fc) = 0.76075229$
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
--->
 $cu (4.10) = 0.46564051$
 $MRC (4.17) = 2.0934E+008$
--->
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, fcc, cc , used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
 $v^* < v^*, y2$ - LHS eq.(4.5) is not satisfied
--->
 $v^* < v^*, c$ - 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) = 0.55615794

MRO (4.17) = 2.4313E+008

--->

u = cu (4.2) = 2.6161250E-005

Mu = MRO

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.22053887

lb = 300.00

l_d = 1360.304

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

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 15.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

Atr = Min(Atr_x,Atr_y) = 157.0796

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

s = 380.00

n = 20.00

Calculation of Mu1-

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

u = 1.3353763E-005

Mu = 1.2706E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00221164

N = 4737.328

fc = 15.00

co (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$

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

From (5.4b), TBDY: $\phi_u = 0.018$

we ((5.4c), TBDY) = $\text{ase} * \text{sh, min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

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

 $f_x = 0.15303423$

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

$\text{af} = 0.43111111$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 51733.333$

$b_{\text{max}} = 400.00$

$h_{\text{max}} = 400.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

$f_y = 0.15303423$

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

$a_f = 0.43111111$

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

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

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

$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

c = confinement factor = 1.27578

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

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

$l_o/l_{ou,min} = l_b/l_d = 0.22053887$

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

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, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$$f_{y2} = 253.4875$$

$$s_{u2} = 0.00365026$$

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

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$$

$$s_{u2} = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

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

For calculation of $e_{su2,nominal}$ and y_2 , sh_2, ft_2, f_{y2} , it is considered
characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1 , sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{s2} = f_s = 253.4875$$

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

$$y_v = 0.0010562$$

$$sh_v = 0.00365026$$

$$ft_v = 304.185$$

$$f_{y_v} = 253.4875$$

$$s_{u_v} = 0.00365026$$

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

$$l_o/l_{o,min} = l_b/l_d = 0.22053887$$

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

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

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

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

y_1 , sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{sv} = f_s = 253.4875$$

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

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.09815014$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.26768221$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.24388823$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 19.13667$$

$$cc (5A.5, TBDY) = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.1260644$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.34381201$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.31325094$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.23431248$$

$$M_u = M_{Rc} (4.14) = 1.2706E+008$$

$$u = s_u (4.1) = 1.3353763E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

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

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

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

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

$$s = 380.00$$

$$n = 20.00$$

Calculation of μ_{2+}

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

$$\mu_u = 2.6161250E-005$$

$$\mu_{2+} = 2.4313E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

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

$$\text{Final value of } \mu_{cu}^* = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.018$$

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

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.018$$

$$\mu_{ve} \text{ (5.4c), TBDY} = \alpha_{se} * \text{sh}_{\min} * f_{yve} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

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

$$f_x = 0.15303423$$

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

$$\alpha_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

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

$$\alpha_f = 0.43111111$$

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

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00165347$$

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

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir \text{ (Length of stirrups along Y)} = 960.00$$

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

$$Asec \text{ (section area)} = 120000.00$$

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir \text{ (Length of stirrups along X)} = 960.00$$

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

$$Asec \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y1 = 0.0010562$$

$$sh1 = 0.00365026$$

$$ft1 = 304.185$$

$$fy1 = 253.4875$$

$$su1 = 0.00365026$$

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

$$lo/lou,min = lb/d = 0.22053887$$

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

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

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

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = fs = 253.4875$$

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

$$y2 = 0.0010562$$

$$sh2 = 0.00365026$$

$$ft2 = 304.185$$

$$fy2 = 253.4875$$

$$su2 = 0.00365026$$

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

$$lo/lou,min = lb/lb,min = 0.22053887$$

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

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

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

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = fs = 253.4875$$

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

$$yv = 0.0010562$$

$$shv = 0.00365026$$

$$ftv = 304.185$$

$$fyv = 253.4875$$

$$suv = 0.00365026$$

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

$$lo/lou,min = lb/d = 0.22053887$$

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

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

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

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fsv = fs = 253.4875$$

```

with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.53536441
2 = Asl,com/(b*d)*(fs2/fc) = 0.19630028
v = Asl,mid/(b*d)*(fsv/fc) = 0.48777647
and confined core properties:
b = 140.00
d = 327.00
d' = 13.00
fcc (5A.2, TBDY) = 19.13667
cc (5A.5, TBDY) = 0.00475778
c = confinement factor = 1.27578
1 = Asl,ten/(b*d)*(fs1/fc) = 0.83497202
2 = Asl,com/(b*d)*(fs2/fc) = 0.30615641
v = Asl,mid/(b*d)*(fsv/fc) = 0.76075229
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) = 0.46564051
MRc (4.17) = 2.0934E+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, fcc, cc, used in lieu of fc, ecu
--->
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) = 0.55615794
MRo (4.17) = 2.4313E+008
--->
u = cu (4.2) = 2.6161250E-005
Mu = MRo
-----

Calculation of ratio lb/ld
-----
Lap Length: lb/ld = 0.22053887
lb = 300.00
ld = 1360.304
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

```

db = 18.00

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

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

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

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

s = 380.00

n = 20.00

Calculation of μ_2 -

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

$\mu = 1.3353763E-005$

$\mu_2 = 1.2706E+008$

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00221164

N = 4737.328

$f_c' = 15.00$

α (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_s) = 0.018$

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

From (5.4b), TBDY: $\mu_c = 0.018$

μ_s ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

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

 $f_x = 0.15303423$

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

$\alpha f = 0.43111111$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

 $f_y = 0.15303423$

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

$\alpha f = 0.43111111$

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

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{f,5} = 0.015$

$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$

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

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

"Theoretical Stress-Strain Model for Confined Concrete."

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

Aconf,max = 75600.00 is the confined core 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 = 0.00 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 = 33066.667 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) = 0.00165347

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

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00165347

Lstir (Length of stirrups along Y) = 960.00

Astir (stirrups area) = 78.53982

Asec (section area) = 120000.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00165347

Lstir (Length of stirrups along X) = 960.00

Astir (stirrups area) = 78.53982

Asec (section area) = 120000.00

s = 380.00

fywe = 555.55

fce = 15.00

From ((5.A5), TBDY), TBDY: cc = 0.00475778

c = confinement factor = 1.27578

y1 = 0.0010562

sh1 = 0.00365026

ft1 = 304.185

fy1 = 253.4875

su1 = 0.00365026

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

lo/lou,min = lb/lb = 0.22053887

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

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

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

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.

with fs1 = fs = 253.4875

with Es1 = Es = 200000.00

y2 = 0.0010562

sh2 = 0.00365026

ft2 = 304.185

fy2 = 253.4875

su2 = 0.00365026

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

lo/lou,min = lb/lb,min = 0.22053887

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, ASCE 41-17.

with fs2 = fs = 253.4875

with Es2 = Es = 200000.00

yv = 0.0010562

shv = 0.00365026

ftv = 304.185

fyv = 253.4875

suv = 0.00365026

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

lo/lou,min = lb/lb = 0.22053887

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

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, ASCE 41-17.

with $fsv = fs = 253.4875$

with $Esv = Es = 200000.00$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.09815014$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.26768221$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.24388823$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 19.13667$$

$$cc (5A.5, TBDY) = 0.00475778$$

c = confinement factor = 1.27578

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1260644$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.34381201$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.31325094$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.23431248$$

$$\text{Mu} = \text{MRc} (4.14) = 1.2706\text{E}+008$$

$$u = su (4.1) = 1.3353763\text{E}-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.22053887$

$$lb = 300.00$$

$$ld = 1360.304$$

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

$$= 1$$

$$db = 18.00$$

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

$fc' = 15.00$, but $fc^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 24.02082$$

$$Ktr = 0.82673491$$

$$Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$$

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

$$s = 380.00$$

$$n = 20.00$$

Calculation of Shear Strength $Vr = \text{Min}(Vr1, Vr2) = 196005.816$

Calculation of Shear Strength at edge 1, $Vr1 = 227350.021$

$$Vr1 = VCol ((10.3), ASCE 41-17) = knl * VCol0$$

$$VCol0 = 227350.021$$

$knl = 1$ (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)

$fc' = 15.00$, but $fc^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$\mu_u = 3.21769$
 $V_u = 0.01054019$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 4737.328$
 $A_g = 80000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

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

$d = 320.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

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

$s/d = 1.1875$

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

$d = 160.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

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

$s/d = 2.375$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, 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) = 357.00

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: $V_s + V_f \leq 164661.611$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 196005.816$

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

$V_{Col0} = 196005.816$

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

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

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

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 23.99609$

$V_u = 0.01054019$

$d = 0.8 \cdot h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

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

$d = 320.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

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

$s/d = 1.1875$

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

$d = 160.00$

Av = 157079.633

fy = 444.44

s = 380.00

Vs2 is multiplied by Col2 = 0.00

s/d = 2.375

Vf ((11-3)-(11.4), ACI 440) = 188111.148

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 $Vf(\alpha, \theta)$, 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: $\theta_1 = b1 + 90^\circ = 90.00$

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

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

dfv = d (figure 11.2, ACI 440) = 357.00

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 <= 164661.611

bw = 200.00

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, $\gamma = 0.90$

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

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

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

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.27578

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 1.5456333E-009$
EDGE -B-
Shear Force, $V_b = -1.5456333E-009$
BOTH EDGES
Axial Force, $F = -4737.328$
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, $V_e/V_r = 0.55718248$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 126675.449$
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.9001E+008$
 $\mu_{1+} = 1.9001E+008$, 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
 $\mu_{1-} = 1.9001E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.9001E+008$
 $\mu_{2+} = 1.9001E+008$, 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
 $\mu_{2-} = 1.9001E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 1.7086748E-005$
 $\mu_u = 1.9001E+008$

with full section properties:

$b = 200.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00442328$
 $N = 4737.328$
 $f_c = 15.00$
 $\omega (5A.5, TBDY) = 0.002$
Final value of ω : $\omega^* = \text{shear_factor} * \text{Max}(\omega_u, \omega_c) = 0.018$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\omega_u = 0.018$
 $\omega_{ve} ((5.4c), TBDY) = \omega_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$
where $f = \alpha_f * \rho_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

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

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$f_y = 0.15303423$$

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

$$a_f = 0.43111111$$

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

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

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

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 960.00$$

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

$$A_{sec} \text{ (section area)} = 120000.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} \text{ (Length of stirrups along X)} = 960.00$$

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

$$A_{sec} \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y_1 = 0.0010562$$

$$sh_1 = 0.00365026$$

$$ft_1 = 304.185$$

$$fy_1 = 253.4875$$

$$su_1 = 0.00365026$$

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

$$l_o/l_{o,min} = l_b/d = 0.22053887$$

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

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

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

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = fs = 253.4875$

with $Es1 = Es = 200000.00$

$y2 = 0.0010562$

$sh2 = 0.00365026$

$ft2 = 304.185$

$fy2 = 253.4875$

$su2 = 0.00365026$

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

$lo/lou, min = lb/lb, min = 0.22053887$

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

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

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

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = fs = 253.4875$

with $Es2 = Es = 200000.00$

$yv = 0.0010562$

$shv = 0.00365026$

$ftv = 304.185$

$fyv = 253.4875$

$su v = 0.00365026$

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

$lo/lou, min = lb/ld = 0.22053887$

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

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

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

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

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fsv = fs = 253.4875$

with $Esv = Es = 200000.00$

$1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.29147618$

$2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.29147618$

$v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.6364888$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

$c = \text{confinement factor} = 1.27578$

$1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.45459588$

$2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.45459588$

$v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.99268896$

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) = 0.40159417

$Mu = MRc$ (4.15) = 1.9001E+008

$u = su$ (4.1) = 1.7086748E-005

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.22053887$

$lb = 300.00$

ld = 1360.304

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 15.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

Atr = Min(Atr_x, Atr_y) = 157.0796

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

s = 380.00

n = 20.00

Calculation of Mu1-

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

u = 1.7086748E-005

Mu = 1.9001E+008

with full section properties:

b = 200.00

d = 357.00

d' = 43.00

v = 0.00442328

N = 4737.328

fc = 15.00

co (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$

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

From (5.4b), TBDY: $\phi_u = 0.018$

we ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

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

 $f_x = 0.15303423$

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

$\text{af} = 0.43111111$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

 $f_y = 0.15303423$

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

$\text{af} = 0.43111111$

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

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\text{ase} = \text{Max}(((\text{Aconf}_{\max} - \text{AnoConf}) / \text{Aconf}_{\max}) * (\text{Aconf}_{\min} / \text{Aconf}_{\max}), 0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

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

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

$c = \text{confinement factor} = 1.27578$

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

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

$lo/lou,min = lb/ld = 0.22053887$

$su_1 = 0.4 * esu1_nominal$ ((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, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

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

$lo/lou,min = lb/lb,min = 0.22053887$

$su_2 = 0.4 * esu2_nominal$ ((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, ASCE 41-17.

with $fs_2 = fs = 253.4875$

with $Es_2 = Es = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$suv = 0.00365026$

using (30) in Biskinis/Fardis (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/d = 0.22053887

su = 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, ASCE 41-17.

with fsv = fs = 253.4875

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.29147618

2 = Asl,com/(b*d)*(fs2/fc) = 0.29147618

v = Asl,mid/(b*d)*(fsv/fc) = 0.6364888

and confined core properties:

b = 140.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

c = confinement factor = 1.27578

1 = Asl,ten/(b*d)*(fs1/fc) = 0.45459588

2 = Asl,com/(b*d)*(fs2/fc) = 0.45459588

v = Asl,mid/(b*d)*(fsv/fc) = 0.99268896

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) = 0.40159417

Mu = MRc (4.15) = 1.9001E+008

u = su (4.1) = 1.7086748E-005

Calculation of ratio lb/d

Lap Length: lb/d = 0.22053887

lb = 300.00

ld = 1360.304

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

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 15.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

Atr = Min(Atr_x,Atr_y) = 157.0796

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

s = 380.00

n = 20.00

Calculation of Mu2+

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

u = 1.7086748E-005

Mu = 1.9001E+008

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e ((5.4c), TBDY) = a_s e^* s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

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

$$f_x = 0.15303423$$

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

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

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

$$a_f = 0.43111111$$

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

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh, \min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

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

$$p_{sh,x} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} (\text{Length of stirrups along Y}) = 960.00$$

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

$$A_{\text{sec}} (\text{section area}) = 120000.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} (\text{Length of stirrups along X}) = 960.00$$

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

$$A_{\text{sec}} (\text{section area}) = 120000.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00475778$

$c =$ confinement factor = 1.27578

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

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

$lo/lou,min = lb/ld = 0.22053887$

$su_1 = 0.4 * esu_1,nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_1,nominal = 0.08$,

For calculation of $esu_1,nominal$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

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

$lo/lou,min = lb/lb,min = 0.22053887$

$su_2 = 0.4 * esu_2,nominal ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $fs_2 = fs = 253.4875$

with $Es_2 = Es = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$su_v = 0.00365026$

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

$lo/lou,min = lb/ld = 0.22053887$

$su_v = 0.4 * esuv,nominal ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $fsv = fs = 253.4875$

with $Esv = Es = 200000.00$

$1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.29147618$

$2 = Asl,com / (b * d) * (fs_2 / fc) = 0.29147618$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 19.13667$

$cc (5A.5, TBDY) = 0.00475778$

$c =$ confinement factor = 1.27578

$1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.45459588$

$2 = Asl,com / (b * d) * (fs_2 / fc) = 0.45459588$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.99268896$

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

--->

$$s_u(4.8) = 0.40159417$$

$$\mu = M R_c(4.15) = 1.9001E+008$$

$$u = s_u(4.1) = 1.7086748E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

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

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

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

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

$$s = 380.00$$

$$n = 20.00$$

Calculation of μ_2

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

$$u = 1.7086748E-005$$

$$\mu = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_c) = 0.018$$

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

$$\text{From (5.4b), TB DY: } \mu = 0.018$$

$$\text{we ((5.4c), TB DY) } = a_s e^* s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

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

$$f_x = 0.15303423$$

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

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

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

$$a_f = 0.43111111$$

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

bmax = 400.00
hmax = 400.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.01016$
bw = 200.00
effective stress from (A.35), $ff,e = 524.0792$

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

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00165347$

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

$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
Lstir (Length of stirrups along Y) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
Lstir (Length of stirrups along X) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

s = 380.00
 $f_{ywe} = 555.55$
fce = 15.00

From ((5.A5), TBDY), TBDY: cc = 0.00475778

c = confinement factor = 1.27578

$y_1 = 0.0010562$
 $sh_1 = 0.00365026$

ft1 = 304.185

fy1 = 253.4875

$su_1 = 0.00365026$

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

$l_o/l_{o,min} = l_b/l_d = 0.22053887$

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

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

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

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$
 $sh_2 = 0.00365026$

ft2 = 304.185

fy2 = 253.4875

$su_2 = 0.00365026$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$

$su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fs_2 = fs = 253.4875$
 with $Es_2 = Es = 200000.00$
 $yv = 0.0010562$
 $shv = 0.00365026$
 $ftv = 304.185$
 $fyv = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.22053887$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $Es_v = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.29147618$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.29147618$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.6364888$

and confined core properties:

$b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.45459588$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.45459588$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.99268896$

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
 --->
 $su (4.8) = 0.40159417$
 $Mu = MRc (4.15) = 1.9001E+008$
 $u = su (4.1) = 1.7086748E-005$

 Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.22053887$
 $lb = 300.00$
 $ld = 1360.304$
 Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 15.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 24.02082$
 $Ktr = 0.82673491$
 $Atr = Min(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis
 $s = 380.00$

n = 20.00

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227350.021$

Calculation of Shear Strength at edge 1, $V_{r1} = 227350.021$

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

$V_{Co10} = 227350.021$

$knl = 1$ (zero step-static loading)

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

= 1 (normal-weight concrete)

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.00988804$

$V_u = 1.5456333E-009$

$d = 0.8 * h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

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

$s/d = 2.375$

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

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

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

$s/d = 1.1875$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$dfv = d$ (figure 11.2, ACI 440) = 357.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$

$bw = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 227350.021$

$V_{r2} = V_{Co2} ((10.3), ASCE 41-17) = knl * V_{Co10}$

$V_{Co10} = 227350.021$

$knl = 1$ (zero step-static loading)

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

= 1 (normal-weight concrete)

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.00525978$

$V_u = 1.5456333E-009$

$d = 0.8 \cdot h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

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

$s/d = 2.375$

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

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

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

$s/d = 1.1875$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, 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: $\theta = b1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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: $V_s + V_f \leq 164661.611$

$b_w = 200.00$

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, $\gamma = 0.90$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

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, $f_c = f_{cm} = 15.00$

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

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, Ecc = 100.00
 Cover Thickness, c = 25.00
 Element Length, L = 3000.00
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length lb = 300.00
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, t = 1.016
 Tensile Strength, ffu = 1055.00
 Tensile Modulus, Ef = 64828.00
 Elongation, efu = 0.01
 Number of directions, NoDir = 1
 Fiber orientations, bi: 0.00°
 Number of layers, NL = 1
 Radius of rounding corners, R = 40.00

 Stepwise Properties

Bending Moment, M = 21.03175
 Shear Force, V2 = 2811.342
 Shear Force, V3 = 0.02136663
 Axial Force, F = -4735.965
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: Ast = 0.00
 -Compression: Asc = 5152.212
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: Ast,ten = 2261.947
 -Compression: Asc,com = 829.3805
 -Middle: Ast,mid = 2060.885
 Mean Diameter of Tension Reinforcement, DbL = 17.77778

 Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \gamma + p = 0.0070088$
 $u = \gamma + p = 0.00778756$

 - Calculation of γ -

$\gamma = (M \cdot L_s / 3) / E_{eff} = 0.00778756$ ((4.29), Biskinis Phd))
 $M_y = 1.9010E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 984.3271
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 8.0093E+012$
 factor = 0.30
 $A_g = 120000.00$
 $f_c' = 15.00$
 $N = 4735.965$
 $E_c \cdot I_g = 2.6698E+013$

 Calculation of Yielding Moment M_y

Calculation of γ and M_y according to Annex 7 -

$\gamma = \text{Min}(\gamma_{ten}, \gamma_{com})$
 $\gamma_{ten} = 6.8134937E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 235.317$
 $d = 357.00$
 $\gamma = 0.51628986$

A = 0.07244171
 B = 0.04953119
 with $pt = 0.0075814$
 $pc = 0.01161597$
 $pv = 0.02886393$
 $N = 4735.965$
 $b = 200.00$
 $" = 0.12044818$
 $y_{comp} = 8.6576330E-006$
 with fc^* (12.3, (ACI 440)) = 16.12972
 $fc = 15.00$
 $fl = 0.93147527$
 $b = b_{max} = 400.00$
 $h = h_{max} = 400.00$
 $Ag = 120000.00$
 $g = pt + pc + pv = 0.07215983$
 $rc = 40.00$
 $Ae/Ac = 0.38686758$
 Effective FRP thickness, $tf = NL*t*\cos(b1) = 1.016$
 effective strain from (12.5) and (12.12), $efe = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 18203.022$
 $y = 0.51604609$
 $A = 0.0719519$
 $B = 0.04924932$
 with $Es = 200000.00$

 Calculation of ratio lb/ld

Lap Length: $ld/ld_{min} = 0.27567359$

$lb = 300.00$

$ld = 1088.244$

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

= 1

$db = 18.00$

Mean strength value of all re-bars: $fy = 444.44$

$fc' = 15.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 24.02082$

$Ktr = 0.82673491$

$Atr = \min(Atr_x, Atr_y) = 157.0796$

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

$s = 380.00$

$n = 20.00$

 - Calculation of p -

From table 10-8: $p = 0.00$

with:

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

shear control ratio $VyE/VCoIOE = 0.82694402$

$d = 357.00$

$s = 0.00$

$t = Av/(bw*s) + 2*tf/bw*(ffe/fs) = Av*Lstir/(Ag*s) + 2*tf/bw*(ffe/fs) = 0.0075814$

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

$Lstir = 960.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2*tf/bw*(ffe/fs)$ is implemented to account for FRP contribution

where $f = 2*tf/bw$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and ffe/fs normalises f to steel strength

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

$NUD = 4735.965$

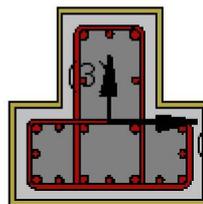
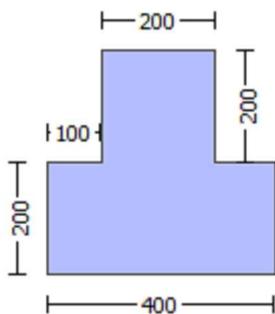
$Ag = 120000.00$

$f_{cE} = 15.00$
 $f_{ytE} = f_{ylE} = 444.44$
 $p_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.07215983$
 $b = 200.00$
 $d = 357.00$
 $f_{cE} = 15.00$

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: Immediate Occupancy (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Shear capacity VRd
Edge: End
Local Axis: (3)



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

Constant Properties

Knowledge Factor, $\gamma = 0.90$
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.
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, $f_c = f_{c_lower_bound} = 10.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 18203.022$

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$

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

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = 47.67334$

Shear Force, $V_a = -0.02136663$

EDGE -B-

Bending Moment, $M_b = 21.03175$

Shear Force, $V_b = 0.02136663$

BOTH EDGES

Axial Force, $F = -4735.965$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl} = 0.00$

-Compression: $A_{slc} = 5152.212$

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 $V_R = \phi V_n = 151052.888$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 167836.542$

$V_{CoI} = 167836.542$

$k_n = 1.00$

displacement_ductility_demand = 3.9788798E-005

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)

$f_c' = 10.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 3.07602$
 $\mu_u = 21.03175$
 $V_u = 0.02136663$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 4735.965$
 $A_g = 80000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$
where:

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

$d = 320.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$

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

$s/d = 1.1875$

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

$d = 160.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$

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

$s/d = 2.375$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

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

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

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

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

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, 1)|)$, with:

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 134445.642$

$b_w = 200.00$

displacement ductility demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 3.0985757E-007$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00778756$ ((4.29), Biskinis Phd)

$M_y = 1.9010E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 984.3271

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 8.0093E+012$

factor = 0.30

$A_g = 120000.00$

$f_c' = 15.00$

$N = 4735.965$

$E_c \cdot I_g = 2.6698E+013$

Calculation of Yielding Moment M_y

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

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

$y_{ten} = 6.8134937E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 235.317$

$d = 357.00$
 $y = 0.51628986$
 $A = 0.07244171$
 $B = 0.04953119$
 with $pt = 0.03167993$
 $pc = 0.01161597$
 $pv = 0.02886393$
 $N = 4735.965$
 $b = 200.00$
 $" = 0.12044818$
 $y_{comp} = 8.6576330E-006$
 with $fc^* (12.3, (ACI 440)) = 16.12972$
 $fc = 15.00$
 $fl = 0.93147527$
 $b = b_{max} = 400.00$
 $h = h_{max} = 400.00$
 $Ag = 120000.00$
 $g = pt + pc + pv = 0.07215983$
 $rc = 40.00$
 $Ae/Ac = 0.38686758$
 Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 18203.022$
 $y = 0.51604609$
 $A = 0.0719519$
 $B = 0.04924932$
 with $Es = 200000.00$

 Calculation of ratio lb/l_d

Lap Length: $l_d/l_{d,min} = 0.27567359$
 $lb = 300.00$
 $l_d = 1088.244$
 Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 444.44$
 $fc' = 15.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 24.02082$
 $K_{tr} = 0.82673491$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = 380.00$
 $n = 20.00$

 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

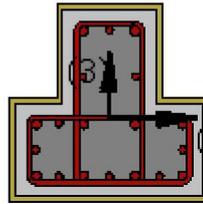
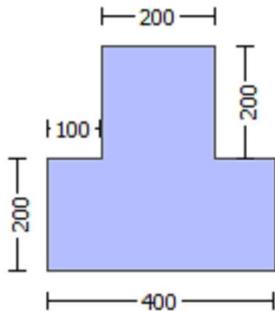
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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, $\gamma = 0.90$

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

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

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

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $E_{cc} = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.27578

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 0.01054019$
EDGE -B-
Shear Force, $V_b = -0.01054019$
BOTH EDGES
Axial Force, $F = -4737.328$
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: $A_{sl,mid} = 2060.885$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.82694402$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 162085.836$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.4313E+008$
 $\mu_{u1+} = 2.4313E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 1.2706E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.4313E+008$
 $\mu_{u2+} = 2.4313E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $\mu_{u2-} = 1.2706E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 2.6161250E-005$
 $\mu_u = 2.4313E+008$

with full section properties:

$b = 200.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00442328$
 $N = 4737.328$
 $f_c = 15.00$
 $\alpha_{co} (5A.5, TBDY) = 0.002$
Final value of α_{cu} : $\alpha_{cu}^* = \text{shear_factor} * \text{Max}(\alpha_{cu}, \alpha_{cc}) = 0.018$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\alpha_{cu} = 0.018$
 $\alpha_{ve} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe}/f_{ce} + \text{Min}(\alpha_{fx}, \alpha_{fy}) = 0.15303423$
where $\alpha_{fx} = \alpha_{f} * \rho_{f} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
 $\alpha_{fx} = 0.15303423$
Expression ((15B.6), TBDY) is modified as $\alpha_{f} = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.01016$$

$$bw = 200.00$$

$$\text{effective stress from (A.35), } ff,e = 524.0792$$

$$fy = 0.15303423$$

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

$$af = 0.43111111$$

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

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.01016$$

$$bw = 200.00$$

$$\text{effective stress from (A.35), } ff,e = 524.0792$$

$$R = 40.00$$

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

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$$psh_{\text{min}} = \text{Min}(psh_x, psh_y) = 0.00165347$$

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

$$psh_x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 960.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 120000.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 960.00$$

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

$$A_{\text{sec}} \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$fy_{we} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y1 = 0.0010562$$

$$sh1 = 0.00365026$$

$$ft1 = 304.185$$

$$fy1 = 253.4875$$

$$su1 = 0.00365026$$

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

$$lo/lou_{\text{min}} = lb/ld = 0.22053887$$

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

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

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.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_1 = fs = 253.4875$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.0010562$
 $sh_2 = 0.00365026$
 $ft_2 = 304.185$
 $fy_2 = 253.4875$
 $su_2 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/lb, min = 0.22053887$
 $su_2 = 0.4 \cdot esu_2, nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_2, nominal = 0.08$,
 For calculation of $esu_2, nominal$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_2 = fs = 253.4875$
 with $Es_2 = Es = 200000.00$
 $yv = 0.0010562$
 $shv = 0.00365026$
 $ftv = 304.185$
 $fyv = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/d = 0.22053887$
 $suv = 0.4 \cdot esuv, nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv, nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv, nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $Esv = Es = 200000.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs_1 / fc) = 0.53536441$
 $2 = Asl, com / (b \cdot d) \cdot (fs_2 / fc) = 0.19630028$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.48777647$
 and confined core properties:
 $b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = Asl, ten / (b \cdot d) \cdot (fs_1 / fc) = 0.83497202$
 $2 = Asl, com / (b \cdot d) \cdot (fs_2 / fc) = 0.30615641$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.76075229$
 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
 --->
 $cu (4.10) = 0.46564051$
 $MRC (4.17) = 2.0934E+008$

--->

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, ν , ν normalised to $b_o \cdot d_o$, instead of $b \cdot d$
- parameters of confined concrete, f_{cc} , ν_{cc} , used in lieu of f_c , ν_c

--->

Subcase: Rupture of tension steel

--->

$\nu^* < \nu^* s_y 2$ - LHS eq.(4.5) is not satisfied

--->

$\nu^* < \nu^* s_c$ - LHS eq.(4.5) is not satisfied

--->

Subcase rejected

--->

New Subcase: Failure of compression zone

--->

$\nu^* < \nu^* c_y 2$ - LHS eq.(4.6) is not satisfied

--->

$\nu^* < \nu^* c_y 1$ - RHS eq.(4.6) is satisfied

--->

$\nu^* c_u$ (4.10) = 0.55615794

MRO (4.17) = 2.4313E+008

--->

$u = \nu^* c_u$ (4.2) = 2.6161250E-005

$M_u = M_{RO}$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$

$l_d = 1360.304$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 18.00$

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

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 24.02082$

$K_{tr} = 0.82673491$

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

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

$s = 380.00$

$n = 20.00$

Calculation of $M_u 1$ -

Calculation of ultimate curvature ν^* according to 4.1, Biskinis/Fardis 2013:

$u = 1.3353763E-005$

$M_u = 1.2706E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$\nu = 0.00221164$

$N = 4737.328$

$f_c = 15.00$

ν_{co} (5A.5, TBDY) = 0.002

Final value of ν^* : $\nu^* = \text{shear_factor} * \text{Max}(\nu_{cu}, \nu_{cc}) = 0.018$

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

From (5.4b), TBDY: $c_u = 0.018$

where ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

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

 $f_x = 0.15303423$

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

$af = 0.43111111$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

 $f_y = 0.15303423$

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

$af = 0.43111111$

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

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

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

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00475778$

$c = \text{confinement factor} = 1.27578$

$y1 = 0.0010562$

$sh1 = 0.00365026$

$ft1 = 304.185$

$fy1 = 253.4875$

$su1 = 0.00365026$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.22053887

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, ASCE 41-17.

with fs1 = fs = 253.4875

with Es1 = Es = 200000.00

y2 = 0.0010562

sh2 = 0.00365026

ft2 = 304.185

fy2 = 253.4875

su2 = 0.00365026

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.22053887

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

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

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

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs2 = fs = 253.4875

with Es2 = Es = 200000.00

yv = 0.0010562

shv = 0.00365026

ftv = 304.185

fyv = 253.4875

suv = 0.00365026

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.22053887

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, ASCE 41-17.

with fsv = fs = 253.4875

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09815014

2 = Asl,com/(b*d)*(fs2/fc) = 0.26768221

v = Asl,mid/(b*d)*(fsv/fc) = 0.24388823

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

c = confinement factor = 1.27578

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1260644

2 = Asl,com/(b*d)*(fs2/fc) = 0.34381201

v = Asl,mid/(b*d)*(fsv/fc) = 0.31325094

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.23431248

Mu = MRc (4.14) = 1.2706E+008

u = su (4.1) = 1.3353763E-005

Calculation of ratio lb/d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$

$l_d = 1360.304$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

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

$f_c' = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 24.02082$

$K_{tr} = 0.82673491$

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

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

$s = 380.00$

$n = 20.00$

Calculation of μ_{2+}

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

$\mu = 2.6161250E-005$

$\mu = 2.4313E+008$

with full section properties:

$b = 200.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00442328$

$N = 4737.328$

$f_c = 15.00$

c_0 (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, c_0) = 0.018$

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

From (5.4b), TBDY: $\mu = 0.018$

we ((5.4c), TBDY) = $a_s * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

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

$f_x = 0.15303423$

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

$a_f = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

$f_y = 0.15303423$

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

$a_f = 0.43111111$

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

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$$u,f = 0.015$$

$$ase = \text{Max}(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.00$$

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 = 75600.00 is the confined core 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 = 0.00 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 = 33066.667 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00165347$$

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

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir \text{ (Length of stirrups along Y)} = 960.00$$

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

$$Asec \text{ (section area)} = 120000.00$$

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir \text{ (Length of stirrups along X)} = 960.00$$

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

$$Asec \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y1 = 0.0010562$$

$$sh1 = 0.00365026$$

$$ft1 = 304.185$$

$$fy1 = 253.4875$$

$$su1 = 0.00365026$$

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

$$lo/lou,min = lb/l_d = 0.22053887$$

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

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

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

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = fs = 253.4875$$

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

$$y2 = 0.0010562$$

$$sh2 = 0.00365026$$

$$ft2 = 304.185$$

$$fy2 = 253.4875$$

$$su2 = 0.00365026$$

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

$$lo/lou,min = lb/l_b,min = 0.22053887$$

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

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

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

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = fs = 253.4875$$

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

$$yv = 0.0010562$$

$$shv = 0.00365026$$

$$ftv = 304.185$$

$f_{yv} = 253.4875$
 $s_{uv} = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.22053887$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5,5), TBDY) = 0.032$
 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 $\gamma_v, \delta_v, f_{tv}, f_{yv}$, it is considered
 characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.
 $\gamma_1, \delta_1, f_{t1}, f_{y1}$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{sv} = f_s = 253.4875$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.53536441$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.19630028$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.48777647$
 and confined core properties:
 $b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.83497202$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.30615641$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.76075229$
 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
 --->
 $cu (4.10) = 0.46564051$
 $MRC (4.17) = 2.0934E+008$
 --->
 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, 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
 --->
 $*cu (4.10) = 0.55615794$

$$M_{Ro} (4.17) = 2.4313E+008$$

--->

$$u = c_u (4.2) = 2.6161250E-005$$

$$M_u = M_{Ro}$$

Calculation of ratio l_b/l_d

$$\text{Lap Length: } l_b/l_d = 0.22053887$$

$$l_b = 300.00$$

$$l_d = 1360.304$$

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

$$= 1$$

$$d_b = 18.00$$

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

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

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

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

$$s = 380.00$$

$$n = 20.00$$

Calculation of M_u

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

$$u = 1.3353763E-005$$

$$M_u = 1.2706E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00221164$$

$$N = 4737.328$$

$$f_c = 15.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$\text{we ((5.4c), TBDY) } = a_s e^* \text{sh, min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

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

$$f_x = 0.15303423$$

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

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

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

$$a_f = 0.43111111$$

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

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

bw = 200.00
effective stress from (A.35), $f_{f,e} = 524.0792$

R = 40.00
Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(\beta_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{f} = 0.015$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) \cdot (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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., 10.11061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

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

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} \cdot A_{stir} / (A_{sec} \cdot s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

s = 380.00

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

c = confinement factor = 1.27578

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

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

$l_o/l_{ou,min} = l_b/l_d = 0.22053887$

$su_1 = 0.4 \cdot esu1_{nominal}$ ((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, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.22053887$

$su_2 = 0.4 \cdot esu2_{nominal}$ ((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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 196005.816$

Calculation of Shear Strength at edge 1, $V_{r1} = 227350.021$

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

$V_{Col0} = 227350.021$

$knl = 1$ (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).

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

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 3.21769$

$\nu_u = 0.01054019$

$d = 0.8 * h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

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

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

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

$s/d = 1.1875$

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

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

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

$s/d = 2.375$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

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

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

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

orientation 1: $\theta = 45^\circ$ and $a = 90^\circ$

$V_f = \text{Min}(|V_f(45, 90)|, |V_f(-45, 90)|)$, with:

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 196005.816$

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

$V_{Col0} = 196005.816$

$knl = 1$ (zero step-static loading)

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

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

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 23.99609$

$\nu_u = 0.01054019$

$d = 0.8 * h = 320.00$

Nu = 4737.328
Ag = 80000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 0.00

where:

Vs1 = 0.00 is calculated for section web, with:

d = 320.00
Av = 157079.633
fy = 444.44
s = 380.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.1875

Vs2 = 0.00 is calculated for section flange, with:

d = 160.00
Av = 157079.633
fy = 444.44
s = 380.00

Vs2 is multiplied by Col2 = 0.00

s/d = 2.375

Vf ((11-3)-(11.4), ACI 440) = 188111.148

f = 0.95, for fully-wrapped sections

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

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

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

This later relation, considered as a function $Vf(\theta, \alpha)$, 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: $\theta = b1 + 90^\circ = 90.00$

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) = 357.00

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 <= 164661.611

bw = 200.00

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, $\phi = 0.90$

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

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

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

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.27578
Element Length, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 1.5456333E-009$
EDGE -B-
Shear Force, $V_b = -1.5456333E-009$
BOTH EDGES
Axial Force, $F = -4737.328$
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 , $V_e/V_r = 0.55718248$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 126675.449$
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 1.9001E+008$
 $Mu_{1+} = 1.9001E+008$, 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
 $Mu_{1-} = 1.9001E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 1.9001E+008$
 $Mu_{2+} = 1.9001E+008$, 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
 $Mu_{2-} = 1.9001E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.7086748E-005$
 $Mu = 1.9001E+008$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e ((5.4c), TBDY) = a_s e^* s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

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

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

Expression ((5.4d), TBDY) for $p_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} (\text{Length of stirrups along Y}) = 960.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 120000.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} (\text{Length of stirrups along X}) = 960.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 120000.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00475778$

$c =$ confinement factor = 1.27578

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/ld = 0.22053887$

$su_1 = 0.4 * esu_1,nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_1,nominal = 0.08$,

For calculation of $esu_1,nominal$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/lb,min = 0.22053887$

$su_2 = 0.4 * esu_2,nominal ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $fs_2 = fs = 253.4875$

with $Es_2 = Es = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$su_v = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/ld = 0.22053887$

$su_v = 0.4 * esuv,nominal ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $fsv = fs = 253.4875$

with $Esv = Es = 200000.00$

$1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.29147618$

$2 = Asl,com / (b * d) * (fs_2 / fc) = 0.29147618$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 19.13667$

$cc (5A.5, TBDY) = 0.00475778$

$c =$ confinement factor = 1.27578

$1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.45459588$

$2 = Asl,com / (b * d) * (fs_2 / fc) = 0.45459588$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.99268896$

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

--->

$$s_u(4.8) = 0.40159417$$

$$\mu = M_{Rc}(4.15) = 1.9001E+008$$

$$u = s_u(4.1) = 1.7086748E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7086748E-005$$

$$\mu = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o(5A.5, \text{ TBDY}) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.018$$

$$\text{we ((5.4c), TBDY) } = a_s e^* s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2) / 3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2) / 3 = 0.00$$

bmax = 400.00
hmax = 400.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.01016$
bw = 200.00
effective stress from (A.35), $ff,e = 524.0792$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00165347$

Expression ((5.4d), TBDY) for $psh_{,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
Lstir (Length of stirrups along Y) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
Lstir (Length of stirrups along X) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

s = 380.00
 $f_{ywe} = 555.55$
fce = 15.00

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

c = confinement factor = 1.27578

$y1 = 0.0010562$
 $sh1 = 0.00365026$

$ft1 = 304.185$

$fy1 = 253.4875$

$su1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{,min} = lb/ld = 0.22053887$

$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = fs = 253.4875$

with $Es1 = Es = 200000.00$

$y2 = 0.0010562$
 $sh2 = 0.00365026$

$ft2 = 304.185$

$fy2 = 253.4875$

$su2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{,min} = lb/lb_{,min} = 0.22053887$

$su_2 = 0.4 * esu_2_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fs_2 = fs = 253.4875$
 with $Es_2 = Es = 200000.00$
 $yv = 0.0010562$
 $shv = 0.00365026$
 $ftv = 304.185$
 $fyv = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.22053887$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $Es_v = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.29147618$
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.29147618$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$

and confined core properties:

$b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.45459588$
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.45459588$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.99268896$

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

$su (4.8) = 0.40159417$

$Mu = MRc (4.15) = 1.9001E+008$

$u = su (4.1) = 1.7086748E-005$

 Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.22053887$

$lb = 300.00$

$ld = 1360.304$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars: $fy = 555.55$

$fc' = 15.00$, but $fc^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 24.02082$

$Ktr = 0.82673491$

$Atr = Min(Atr_x, Atr_y) = 157.0796$

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

n = 20.00

Calculation of Mu2+

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$u = 1.7086748E-005$

$Mu = 1.9001E+008$

with full section properties:

b = 200.00

d = 357.00

d' = 43.00

v = 0.00442328

N = 4737.328

$f_c = 15.00$

ϕ_o (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u = \text{shear_factor} * \text{Max}(\phi_u, \phi_o) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.018$

ϕ_{we} ((5.4c), TBDY) = $\text{ase} * \text{sh}_{,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.15303423$

where $\phi = \text{af} * \text{pf} * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.15303423$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\text{af} = 0.43111111$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 51733.333$

$b_{\text{max}} = 400.00$

$h_{\text{max}} = 400.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

$\phi_y = 0.15303423$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\text{af} = 0.43111111$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 0.00$

$b_{\text{max}} = 400.00$

$h_{\text{max}} = 400.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{fe} = 524.0792$

R = 40.00

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\text{ase} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$\text{psh}_{,\text{min}} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00165347$

Expression ((5.4d), TBDY) for $\text{psh}_{,\text{min}}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir (\text{Length of stirrups along } Y) = 960.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 120000.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir (\text{Length of stirrups along } X) = 960.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 120000.00$$

$$s = 380.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y1 = 0.0010562$$

$$sh1 = 0.00365026$$

$$ft1 = 304.185$$

$$fy1 = 253.4875$$

$$su1 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.22053887$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = fs = 253.4875$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0010562$$

$$sh2 = 0.00365026$$

$$ft2 = 304.185$$

$$fy2 = 253.4875$$

$$su2 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.22053887$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$y2, sh2,ft2,fy2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = fs = 253.4875$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0010562$$

$$shv = 0.00365026$$

$$ftv = 304.185$$

$$fyv = 253.4875$$

$$suv = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.22053887$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv_nominal = 0.08,$$

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.

$$yv, shv,ftv,fyv, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fsv = fs = 253.4875$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.29147618$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.29147618$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$$

and confined core properties:

$$b = 140.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 19.13667$$

$$cc (5A.5, TBDY) = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$1 = A_{sl,ten}/(b*d)*(fs1/fc) = 0.45459588$$

$$2 = A_{sl,com}/(b*d)*(fs2/fc) = 0.45459588$$

$$v = A_{sl,mid}/(b*d)*(fsv/fc) = 0.99268896$$

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

--->

$$su (4.8) = 0.40159417$$

$$Mu = MRc (4.15) = 1.9001E+008$$

$$u = su (4.1) = 1.7086748E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$fc' = 15.00, \text{ but } fc'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of Mu_2 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7086748E-005$$

$$Mu = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$fc = 15.00$$

$$co (5A.5, TBDY) = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.018$$

$$\text{we ((5.4c), TBDY) } = ase^* sh_{, \min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.15303423$$

where $f = af * pf * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$
 $af = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $ff,e = 524.0792$

$f_y = 0.15303423$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $ff,e = 524.0792$

$R = 40.00$

Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

c = confinement factor = 1.27578

$y1 = 0.0010562$

$sh1 = 0.00365026$

$ft1 = 304.185$

$fy1 = 253.4875$

$su1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.22053887$

$su1 = 0.4*es_{u1_nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u1_nominal} = 0.08$,

For calculation of $es_{u1_nominal}$ and $y1, sh1, ft1, fy1$, it is considered

characteristic value $f_{sy1} = f_{s1}/1.2$, 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, ASCE 41-17.

with $f_{s1} = f_s = 253.4875$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $f_{s2} = f_s = 253.4875$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$su_v = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.22053887$

$su_v = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $f_{sv} = f_s = 253.4875$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.29147618$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.29147618$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.6364888$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 19.13667$

$cc (5A.5, TBDY) = 0.00475778$

c = confinement factor = 1.27578

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.45459588$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.45459588$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.99268896$

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

$su (4.8) = 0.40159417$

$Mu = MRc (4.15) = 1.9001E+008$

u = $su (4.1) = 1.7086748E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$

$l_d = 1360.304$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f'_c = 15.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227350.021$

Calculation of Shear Strength at edge 1, $V_{r1} = 227350.021$

$$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$$

$$V_{Col0} = 227350.021$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f'_c = 15.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu_u = 0.00988804$$

$$V_u = 1.5456333E-009$$

$$d = 0.8 * h = 320.00$$

$$N_u = 4737.328$$

$$A_g = 80000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 0.00$$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$$d = 160.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s1} is multiplied by $Col1 = 0.00$

$$s/d = 2.375$$

$V_{s2} = 0.00$ is calculated for section flange, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s2} is multiplied by $Col2 = 0.00$

$$s/d = 1.1875$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 188111.148$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \theta = 45^\circ + 90^\circ = 135^\circ$$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 357.00$$

$$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$
 $bw = 200.00$

Calculation of Shear Strength at edge 2, $V_r2 = 227350.021$
 $V_r2 = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 227350.021$
 $knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.00525978$

$V_u = 1.5456333E-009$

$d = 0.8 * h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 2.375$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.1875$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$

$bw = 200.00$

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, $\phi = 0.90$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
 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, $f_c = f_{cm} = 15.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 18203.022$
 Steel Elasticity, $E_s = 200000.00$
 Max Height, $H_{max} = 400.00$
 Min Height, $H_{min} = 200.00$
 Max Width, $W_{max} = 400.00$
 Min Width, $W_{min} = 200.00$
 Eccentricity, $E_{cc} = 100.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -136.3192$
 Shear Force, $V_2 = 2811.342$
 Shear Force, $V_3 = 0.02136663$
 Axial Force, $F = -4735.965$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl} = 0.00$
 -Compression: $A_{slc} = 5152.212$
 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 $u_{,R} = \phi \cdot u = 0.00187569$
 $u = y + p = 0.0020841$

- Calculation of y -

$y = (M_y \cdot L_s / 3) / E_{leff} = 0.0020841$ ((4.29), Biskinis Phd))
 $M_y = 1.3657E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00
 From table 10.5, ASCE 41_17: $E_{leff} = \text{factor} \cdot E_c \cdot I_g = 6.5531E+012$
 factor = 0.30
 $A_g = 120000.00$
 $f_c' = 15.00$
 $N = 4735.965$

$$E_c I_g = 2.1844E+013$$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to Annex 7 -

$$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$$

$$y_{\text{ten}} = 5.8874222E-006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 235.317$$

$$d = 357.00$$

$$y = 0.44020389$$

$$A = 0.07244171$$

$$B = 0.04070755$$

$$\text{with } p_t = 0.0075814$$

$$p_c = 0.01724796$$

$$p_v = 0.03766391$$

$$N = 4735.965$$

$$b = 200.00$$

$$" = 0.12044818$$

$$y_{\text{comp}} = 1.0162905E-005$$

$$\text{with } f_c^* (12.3, \text{ACI 440}) = 16.12972$$

$$f_c = 15.00$$

$$f_l = 0.93147527$$

$$b = b_{\text{max}} = 400.00$$

$$h = h_{\text{max}} = 400.00$$

$$A_g = 120000.00$$

$$g = p_t + p_c + p_v = 0.07215983$$

$$r_c = 40.00$$

$$A_e / A_c = 0.38686758$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$\text{effective strain from (12.5) and (12.12), } \epsilon_{fe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 18203.022$$

$$y = 0.43961224$$

$$A = 0.0719519$$

$$B = 0.04042568$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio l_b / l_d

$$\text{Lap Length: } l_d / l_d, \text{min} = 0.27567359$$

$$l_b = 300.00$$

$$l_d = 1088.244$$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 444.44$$

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

- Calculation of ρ_p -

$$\text{From table 10-8: } \rho_p = 0.00$$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$

shear control ratio $V_{yE}/V_{CoIE} = 0.55718248$

$d = 357.00$

$s = 0.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.0075814$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 960.00$, 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.

$N_{UD} = 4735.965$

$A_g = 120000.00$

$f_{cE} = 15.00$

$f_{ytE} = f_{ylE} = 444.44$

$\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.07215983$

$b = 200.00$

$d = 357.00$

$f_{cE} = 15.00$

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

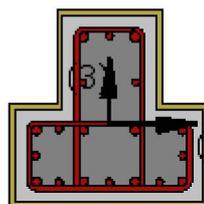
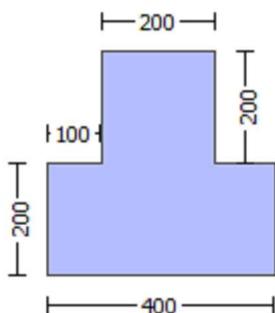
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

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, $\gamma = 0.90$
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.
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, $f_c = f_{c_lower_bound} = 10.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 18203.022$
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, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

Max Height, $H_{max} = 400.00$
Min Height, $H_{min} = 200.00$
Max Width, $W_{max} = 400.00$
Min Width, $W_{min} = 200.00$
Eccentricity, $Ecc = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -1.1892E+007$
Shear Force, $V_a = -3961.043$
EDGE -B-
Bending Moment, $M_b = 1473.353$
Shear Force, $V_b = 3961.043$
BOTH EDGES
Axial Force, $F = -4742.638$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 2375.044$
-Compression: $As_c = 2777.168$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1231.504$
-Compression: $As_{l,com} = 1231.504$
-Middle: $As_{l,mid} = 2689.203$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 144111.676$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI0} = 160124.085$
 $V_{CoI} = 160124.085$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.02386949$

NOTE: In expression (10-3) 'Vs' is replaced by ' $V_s + \phi V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 10.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 1.1892E+007$
 $V_u = 3961.043$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 4742.638$
 $A_g = 80000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$
where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 2.375$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.1875$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $\phi = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:
total thickness per orientation, $t_{f1} = NL \cdot t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 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: $V_s + V_f \leq 134445.642$
 $b_w = 200.00$

$displacement_ductility_demand$ is calculated as δ / y

- Calculation of δ / y for END A -
for rotation axis 3 and integ. section (a)

From analysis, chord rotation $\theta = 0.00049783$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.02085615$ ((4.29), Biskinis Phd))
 $M_y = 1.3657E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3002.161
From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 6.5531E+012$
 $factor = 0.30$
 $A_g = 120000.00$

$f_c' = 15.00$
 $N = 4742.638$
 $E_c \cdot I_g = 2.1844E+013$

Calculation of Yielding Moment M_y

Calculation of I_y and M_y according to Annex 7 -

 $y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 5.8874430E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 235.317$
 $d = 357.00$
 $y = 0.44020587$
 $A = 0.0724421$
 $B = 0.04070795$
with $pt = 0.01724796$
 $pc = 0.01724796$
 $pv = 0.03766391$
 $N = 4742.638$
 $b = 200.00$
 $" = 0.12044818$
 $y_{\text{comp}} = 1.0162879E-005$
with $f_c' (12.3, (ACI 440)) = 16.12972$
 $f_c = 15.00$
 $fl = 0.93147527$
 $b = b_{\text{max}} = 400.00$
 $h = h_{\text{max}} = 400.00$
 $A_g = 120000.00$
 $g = pt + pc + pv = 0.07215983$
 $rc = 40.00$
 $A_e/A_c = 0.38686758$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 18203.022$
 $y = 0.43961339$
 $A = 0.0719516$
 $B = 0.04042568$
with $E_s = 200000.00$

Calculation of ratio l_b/d

Lap Length: $l_d/d, \text{min} = 0.27567359$
 $l_b = 300.00$
 $l_d = 1088.244$
Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
Mean strength value of all re-bars: $f_y = 444.44$
 $f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 24.02082$
 $K_{tr} = 0.82673491$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = 380.00$
 $n = 20.00$

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

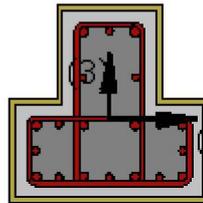
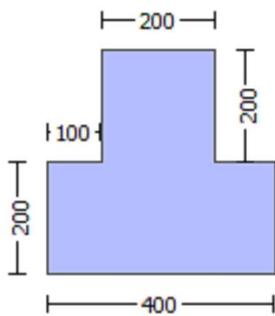
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

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, $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.27578

Element Length, L = 3000.00
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length l_o = 300.00
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, f_{fu} = 1055.00
Tensile Modulus, E_f = 64828.00
Elongation, e_{fu} = 0.01
Number of directions, NoDir = 1
Fiber orientations, b_i : 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, V_a = 0.01054019
EDGE -B-
Shear Force, V_b = -0.01054019
BOTH EDGES
Axial Force, F = -4737.328
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 = 0.82694402
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 162085.836$
with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 2.4313E+008$
 $Mu_{1+} = 2.4313E+008$, 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
 $Mu_{1-} = 1.2706E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 2.4313E+008$
 $Mu_{2+} = 2.4313E+008$, 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
 $Mu_{2-} = 1.2706E+008$, 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:
 $\phi_u = 2.6161250E-005$
 $Mu = 2.4313E+008$

with full section properties:
 $b = 200.00$
 $d = 357.00$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e(5.4c, TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x}(5.4d, TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} (\text{Length of stirrups along Y}) = 960.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 120000.00$$

$$p_{sh,y}(5.4d, TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} (\text{Length of stirrups along X}) = 960.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 120000.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$y1 = 0.0010562$
 $sh1 = 0.00365026$
 $ft1 = 304.185$
 $fy1 = 253.4875$
 $su1 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/d = 0.22053887$
 $su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fs1 = fs = 253.4875$
 with $Es1 = Es = 200000.00$

$y2 = 0.0010562$
 $sh2 = 0.00365026$
 $ft2 = 304.185$
 $fy2 = 253.4875$
 $su2 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.22053887$
 $su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2,ft2,fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs2 = fs = 253.4875$
 with $Es2 = Es = 200000.00$

$yv = 0.0010562$
 $shv = 0.00365026$
 $ftv = 304.185$
 $fyv = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/d = 0.22053887$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $Esv = Es = 200000.00$

$1 = Asl,ten/(b*d)*(fs1/fc) = 0.53536441$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.19630028$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.48777647$

and confined core properties:

$b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.83497202$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.30615641$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.76075229$

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) = 0.46564051

MRC (4.17) = 2.0934E+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, fcc, cc, used in lieu of fc, ecu

---->

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) = 0.55615794

MRO (4.17) = 2.4313E+008

---->

u = cu (4.2) = 2.6161250E-005

Mu = MRO

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.22053887

lb = 300.00

l_d = 1360.304

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 15.00, but fc^{0.5} <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

Atr = Min(Atr_x,Atr_y) = 157.0796

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = 380.00

n = 20.00

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.3353763E-005$$

$$\mu_u = 1.2706E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00221164$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$\omega (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.018$$

$$\mu_w \text{ ((5.4c), TBDY) } = a_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

Expression ((5.4d), TBDY) for $p_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 960.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 120000.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 960.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

Asec (section area) = 120000.00

s = 380.00

fywe = 555.55

fce = 15.00

From ((5.A5), TBDY), TBDY: cc = 0.00475778

c = confinement factor = 1.27578

y1 = 0.0010562

sh1 = 0.00365026

ft1 = 304.185

fy1 = 253.4875

su1 = 0.00365026

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.22053887

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE 41-17.

with fs1 = fs = 253.4875

with Es1 = Es = 200000.00

y2 = 0.0010562

sh2 = 0.00365026

ft2 = 304.185

fy2 = 253.4875

su2 = 0.00365026

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.22053887

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE 41-17.

with fs2 = fs = 253.4875

with Es2 = Es = 200000.00

yv = 0.0010562

shv = 0.00365026

ftv = 304.185

fyv = 253.4875

suv = 0.00365026

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.22053887

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE 41-17.

with fsv = fs = 253.4875

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09815014

2 = Asl,com/(b*d)*(fs2/fc) = 0.26768221

v = Asl,mid/(b*d)*(fsv/fc) = 0.24388823

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

c = confinement factor = 1.27578

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1260644

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.34381201$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.31325094$$

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

$$s_u(4.9) = 0.23431248$$

$$M_u = M_{Rc}(4.14) = 1.2706E+008$$

$$u = s_u(4.1) = 1.3353763E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of M_u2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 2.6161250E-005$$

$$M_u = 2.4313E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } c_u = 0.018$$

$$w_e((5.4c), \text{TB DY}) = a_s e^* s_{h, \min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $ff,e = 524.0792$

$R = 40.00$

Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00165347$

Expression ((5.4d), TBDY) for $psh_{,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh_x ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

psh_y ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

c = confinement factor = 1.27578

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_0/l_{ou,min} = l_b/l_d = 0.22053887$

$su_1 = 0.4 * esu_{1,nominal}$ ((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, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
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, ASCE 41-17.
with $fs_2 = fs = 253.4875$
with $Es_2 = Es = 200000.00$
 $y_v = 0.0010562$
 $sh_v = 0.00365026$
 $ft_v = 304.185$
 $fy_v = 253.4875$
 $suv = 0.00365026$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.22053887$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
considering characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsv = fsv/1.2$, 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, ASCE 41-17.
with $fsv = fs = 253.4875$
with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.53536441$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.19630028$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.48777647$
and confined core properties:
 $b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.83497202$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.30615641$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.76075229$
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
---->
 $c_u (4.10) = 0.46564051$
 $M_{Rc} (4.17) = 2.0934E+008$
---->
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 $b*d$
- f_{cc}, c_c 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

--->

*cu (4.10) = 0.55615794

MRO (4.17) = 2.4313E+008

--->

u = cu (4.2) = 2.6161250E-005

Mu = MRO

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.22053887

lb = 300.00

l_d = 1360.304

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 15.00, but $fc'^{0.5} < 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

Atr = Min(Atr_x, Atr_y) = 157.0796

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = 380.00

n = 20.00

Calculation of Mu₂-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.3353763E-005

Mu = 1.2706E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00221164

N = 4737.328

fc = 15.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = shear_factor * Max(cu, cc) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.018

we ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + Min(f_x, f_y) = 0.15303423$

where f = $af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.15303423

Expression ((15B.6), TBDY) is modified as $af = 1 - (Unconfined\ area) / (total\ area)$

af = 0.43111111

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$

bmax = 400.00
hmax = 400.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.01016$
bw = 200.00
effective stress from (A.35), $ff,e = 524.0792$

fy = 0.15303423
Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$
af = 0.43111111
with Unconfined area = $((bmax-2R)^2 + (hmax-2R)^2)/3 = 0.00$
bmax = 400.00
hmax = 400.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.01016$
bw = 200.00
effective stress from (A.35), $ff,e = 524.0792$

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 = $Max(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.00$
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 = 75600.00 is the confined core 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 = 0.00 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 = 33066.667 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
psh,min = $Min(psh,x, psh,y) = 0.00165347$
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00165347$
Lstir (Length of stirrups along Y) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00165347$
Lstir (Length of stirrups along X) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

s = 380.00
fywe = 555.55
fce = 15.00
From ((5.A5), TBDY), TBDY: $cc = 0.00475778$
c = confinement factor = 1.27578
y1 = 0.0010562
sh1 = 0.00365026
ft1 = 304.185
fy1 = 253.4875
su1 = 0.00365026
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
lo/lou,min = $lb/d = 0.22053887$
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, ASCE 41-17.
with fs1 = fs = 253.4875

with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0010562$
 $sh_2 = 0.00365026$
 $ft_2 = 304.185$
 $fy_2 = 253.4875$
 $su_2 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_0/l_{ou,min} = l_b/l_{b,min} = 0.22053887$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fs_2 = fs = 253.4875$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0010562$
 $sh_v = 0.00365026$
 $ft_v = 304.185$
 $fy_v = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_0/l_{ou,min} = l_b/l_d = 0.22053887$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.09815014$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.26768221$
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.24388823$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.1260644$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.34381201$
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.31325094$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_s, y_2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.23431248$
 $M_u = MR_c (4.14) = 1.2706E+008$
 $u = su (4.1) = 1.3353763E-005$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$
 $l_b = 300.00$
 $l_d = 1360.304$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 15.00$, but $fc^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 24.02082$
 $Ktr = 0.82673491$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis
 $s = 380.00$
 $n = 20.00$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 196005.816$

Calculation of Shear Strength at edge 1, $V_{r1} = 227350.021$
 $V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = knl * V_{Col0}$
 $V_{Col0} = 227350.021$
 $knl = 1$ (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)
 $fc' = 15.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 3.21769$

$V_u = 0.01054019$

$d = 0.8 * h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.1875$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 2.375$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 188111.148$

$f = 0.95$, 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 $V_f(\alpha, a)$, 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: $\alpha = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$

$b_w = 200.00$

 Calculation of Shear Strength at edge 2, $V_{r2} = 196005.816$

$$Vr2 = VCol \text{ ((10.3), ASCE 41-17)} = knl * VCol0$$

$$VCol0 = 196005.816$$

$$knl = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$fc' = 15.00, \text{ but } fc^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$Mu = 23.99609$$

$$Vu = 0.01054019$$

$$d = 0.8 * h = 320.00$$

$$Nu = 4737.328$$

$$Ag = 80000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } Vs = Vs1 + Vs2 = 0.00$$

where:

Vs1 = 0.00 is calculated for section web, with:

$$d = 320.00$$

$$Av = 157079.633$$

$$fy = 444.44$$

$$s = 380.00$$

Vs1 is multiplied by Col1 = 0.00

$$s/d = 1.1875$$

Vs2 = 0.00 is calculated for section flange, with:

$$d = 160.00$$

$$Av = 157079.633$$

$$fy = 444.44$$

$$s = 380.00$$

Vs2 is multiplied by Col2 = 0.00

$$s/d = 2.375$$

$$Vf \text{ ((11-3)-(11.4), ACI 440)} = 188111.148$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

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.

$$\text{orientation 1: } \alpha = b1 + 90^\circ = 90.00$$

$$Vf = \text{Min}(|Vf(45, \alpha)|, |Vf(-45, \alpha)|), \text{ with:}$$

$$\text{total thickness per orientation, } tf1 = NL * t / NoDir = 1.016$$

$$dfv = d \text{ (figure 11.2, ACI 440)} = 357.00$$

$$ffe \text{ ((11-5), ACI 440)} = 259.312$$

$$Ef = 64828.00$$

$$fe = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } fu = 0.01$$

$$\text{From (11-11), ACI 440: } Vs + Vf \leq 164661.611$$

$$bw = 200.00$$

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, $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $fc = fcm = 15.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.27578

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = 1.5456333E-009$

EDGE -B-

Shear Force, $V_b = -1.5456333E-009$

BOTH EDGES

Axial Force, $F = -4737.328$

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: $A_{sl,mid} = 2689.203$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.55718248$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 126675.449$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.9001E+008$

$M_{u1+} = 1.9001E+008$, 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

$M_{u1-} = 1.9001E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.9001E+008$

$M_{u2+} = 1.9001E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{-} = 1.9001E+008$, 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 u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7086748E-005$$

$$Mu = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir (\text{Length of stirrups along } Y) = 960.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 120000.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir (\text{Length of stirrups along } X) = 960.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 120000.00$$

$$s = 380.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y1 = 0.0010562$$

$$sh1 = 0.00365026$$

$$ft1 = 304.185$$

$$fy1 = 253.4875$$

$$su1 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.22053887$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = fs = 253.4875$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0010562$$

$$sh2 = 0.00365026$$

$$ft2 = 304.185$$

$$fy2 = 253.4875$$

$$su2 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.22053887$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$y2, sh2,ft2,fy2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = fs = 253.4875$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0010562$$

$$shv = 0.00365026$$

$$ftv = 304.185$$

$$fyv = 253.4875$$

$$suv = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.22053887$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv_nominal = 0.08,$$

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.

$$yv, shv,ftv,fyv, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fsv = fs = 253.4875$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.29147618$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.29147618$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$$

and confined core properties:

$$b = 140.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 19.13667$$

$$cc (5A.5, TBDY) = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$1 = A_{sl,ten}/(b*d)*(fs1/fc) = 0.45459588$$

$$2 = A_{sl,com}/(b*d)*(fs2/fc) = 0.45459588$$

$$v = A_{sl,mid}/(b*d)*(fsv/fc) = 0.99268896$$

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

--->

$$su (4.8) = 0.40159417$$

$$Mu = MRc (4.15) = 1.9001E+008$$

$$u = su (4.1) = 1.7086748E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$fc' = 15.00, \text{ but } fc'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of Mu_1 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7086748E-005$$

$$Mu = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$fc = 15.00$$

$$co (5A.5, TBDY) = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.018$$

$$\text{we ((5.4c), TBDY) } = ase^* sh_{, \min} * fy_{we}/f_{ce} + \text{Min}(fx, fy) = 0.15303423$$

where $f = af * pf * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$
 $af = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $ff,e = 524.0792$

$f_y = 0.15303423$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $ff,e = 524.0792$

$R = 40.00$

Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

c = confinement factor = 1.27578

$y1 = 0.0010562$

$sh1 = 0.00365026$

$ft1 = 304.185$

$fy1 = 253.4875$

$su1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/d = 0.22053887$

$su1 = 0.4*esu1_{nominal}$ ((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 $f_{sy1} = f_{s1}/1.2$, 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, ASCE 41-17.

with $f_{s1} = f_s = 253.4875$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $f_{s2} = f_s = 253.4875$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$su_v = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.22053887$

$su_v = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $f_{sv} = f_s = 253.4875$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.29147618$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.29147618$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.6364888$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 19.13667$

$cc (5A.5, TBDY) = 0.00475778$

c = confinement factor = 1.27578

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.45459588$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.45459588$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.99268896$

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

$su (4.8) = 0.40159417$

$Mu = MRc (4.15) = 1.9001E+008$

$u = su (4.1) = 1.7086748E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$

$l_d = 1360.304$

Calculation of $I_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.7086748E-005$$

$$\mu_u = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and
is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00165347$

Expression ((5.4d), TBDY) for psh_{min} has been multiplied by 0.3 according to 15.7.1.3 for members without
earthquake detailing (90° closed stirrups)

 psh_x ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 psh_y ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

$c = \text{confinement factor} = 1.27578$

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$
and also multiplied by the $shear_factor$ according to 15.7.1.4, with
 $Shear_factor = 1.00$

$lo/lou_{min} = lb/ld = 0.22053887$

$su_1 = 0.4 * esu1_{nominal}$ ((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, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$
and also multiplied by the $shear_factor$ according to 15.7.1.4, with
 $Shear_factor = 1.00$

$lo/lou_{min} = lb/lb_{min} = 0.22053887$

$su_2 = 0.4 * esu2_{nominal}$ ((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, ASCE 41-17.

with $fs_2 = fs = 253.4875$

with $Es_2 = Es = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$suv = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$
and also multiplied by the $shear_factor$ according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.22053887

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, ASCE 41-17.

with fsv = fs = 253.4875

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.29147618

2 = Asl,com/(b*d)*(fs2/fc) = 0.29147618

v = Asl,mid/(b*d)*(fsv/fc) = 0.6364888

and confined core properties:

b = 140.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

c = confinement factor = 1.27578

1 = Asl,ten/(b*d)*(fs1/fc) = 0.45459588

2 = Asl,com/(b*d)*(fs2/fc) = 0.45459588

v = Asl,mid/(b*d)*(fsv/fc) = 0.99268896

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) = 0.40159417

Mu = MRc (4.15) = 1.9001E+008

u = su (4.1) = 1.7086748E-005

Calculation of ratio lb/d

Lap Length: lb/d = 0.22053887

lb = 300.00

ld = 1360.304

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 15.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

Atr = $\text{Min}(Atr_x, Atr_y)$ = 157.0796

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = 380.00

n = 20.00

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.7086748E-005

Mu = 1.9001E+008

with full section properties:

b = 200.00

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 960.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 120000.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} \text{ (Length of stirrups along X)} = 960.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00475778$$

$c = \text{confinement factor} = 1.27578$
 $y1 = 0.0010562$
 $sh1 = 0.00365026$
 $ft1 = 304.185$
 $fy1 = 253.4875$
 $su1 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.22053887$
 $su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fs1 = fs = 253.4875$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0010562$
 $sh2 = 0.00365026$
 $ft2 = 304.185$
 $fy2 = 253.4875$
 $su2 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.22053887$
 $su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fs2 = fs = 253.4875$
 with $Es2 = Es = 200000.00$
 $yv = 0.0010562$
 $shv = 0.00365026$
 $ftv = 304.185$
 $fyv = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.22053887$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.29147618$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.29147618$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$
 and confined core properties:
 $b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.45459588$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.45459588$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.99268896$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs, y2$ - LHS eq.(4.5) is not satisfied

--->
v < v_{s,c} - RHS eq.(4.5) is satisfied

--->
su (4.8) = 0.40159417
Mu = MRc (4.15) = 1.9001E+008
u = su (4.1) = 1.7086748E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.22053887

lb = 300.00

l_d = 1360.304

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: f_y = 555.55

f_c' = 15.00, but f_c'^{0.5} <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

K_{tr} = 0.82673491

A_{tr} = Min(A_{tr_x}, A_{tr_y}) = 157.0796

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

s = 380.00

n = 20.00

Calculation of Shear Strength Vr = Min(Vr1, Vr2) = 227350.021

Calculation of Shear Strength at edge 1, Vr1 = 227350.021

Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0

VCol0 = 227350.021

knl = 1 (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

f_c' = 15.00, but f_c'^{0.5} <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 0.00988804

Vu = 1.5456333E-009

d = 0.8*h = 320.00

Nu = 4737.328

Ag = 80000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 0.00

where:

Vs1 = 0.00 is calculated for section web, with:

d = 160.00

Av = 157079.633

f_y = 444.44

s = 380.00

Vs1 is multiplied by Col1 = 0.00

s/d = 2.375

Vs2 = 0.00 is calculated for section flange, with:

d = 320.00

Av = 157079.633

f_y = 444.44

s = 380.00

Vs2 is multiplied by Col2 = 0.00

s/d = 1.1875

Vf ((11-3)-(11.4), ACI 440) = 188111.148

f = 0.95, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $tf1 = NL * t / \text{NoDir} = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 357.00

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: $V_s + V_f \leq 164661.611$

$bw = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 227350.021$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $knl * V_{Col0}$

$V_{Col0} = 227350.021$

$knl = 1$ (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).

$\gamma_c = 1$ (normal-weight concrete)

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.00525978$

$V_u = 1.5456333E-009$

$d = 0.8 * h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 2.375$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.1875$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $tf1 = NL * t / \text{NoDir} = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 357.00

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: $V_s + V_f \leq 164661.611$

$bw = 200.00$

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, $\gamma = 0.90$
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
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, $f_c = f_{cm} = 15.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 18203.022$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 400.00$
Min Height, $H_{min} = 200.00$
Max Width, $W_{max} = 400.00$
Min Width, $W_{min} = 200.00$
Eccentricity, $E_{cc} = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -1284.318$
Shear Force, $V_2 = -3961.043$
Shear Force, $V_3 = 0.77690092$
Axial Force, $F = -4742.638$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl} = 2375.044$
-Compression: $A_{sc} = 2777.168$
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, $DbL = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.0501325$

$$u = y + p = 0.05570277$$

- Calculation of y -

$$y = (M_y * L_s / 3) / E_{eff} = 0.01370277 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 1.9917E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 1653.13$$

$$\text{From table 10.5, ASCE 41-17: } E_{eff} = \text{factor} * E_c * I_g = 8.0093E+012$$

$$\text{factor} = 0.30$$

$$A_g = 120000.00$$

$$f_c' = 15.00$$

$$N = 4742.638$$

$$E_c * I_g = 2.6698E+013$$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

$$\text{flange width, } b = 400.00$$

$$\text{web width, } b_w = 200.00$$

$$\text{flange thickness, } t = 200.00$$

$$y = \text{Min}(y_{ten}, y_{com})$$

$$y_{ten} = 5.8877969E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 235.317$$

$$d = 357.00$$

$$y = 0.44023952$$

$$A = 0.03622105$$

$$B = 0.0247658$$

$$\text{with } p_t = 0.0075814$$

$$p_c = 0.00580799$$

$$p_v = 0.01443197$$

$$N = 4742.638$$

$$b = 400.00$$

$$" = 0.12044818$$

$$y_{comp} = 1.0200757E-005$$

$$\text{with } f_c' \text{ (12.3, (ACI 440))} = 16.19674$$

$$f_c = 15.00$$

$$f_l = 0.93147527$$

$$b = b_{max} = 400.00$$

$$h = h_{max} = 400.00$$

$$A_g = 120000.00$$

$$g = p_t + p_c + p_v = 0.03607992$$

$$r_c = 40.00$$

$$A_e / A_c = 0.40981737$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$\text{effective strain from (12.5) and (12.12), } e_{fe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 18203.022$$

$$y = 0.43980075$$

$$A = 0.03597623$$

$$B = 0.02462466$$

$$\text{with } E_s = 200000.00$$

CONFIRMATION: $y = 0.43980075 < t/d$

Calculation of ratio I_b / I_d

$$\text{Lap Length: } I_d / I_{d,min} = 0.27567359$$

$$I_b = 300.00$$

$$I_d = 1088.244$$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 444.44$

$$f'_c = 15.00, \text{ but } f'_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

- Calculation of p -

From table 10-8: $p = 0.042$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/d < 1$

$$\text{shear control ratio } V_{yE}/V_{CoIE} = 0.82694402$$

$$d = 357.00$$

$$s = 0.00$$

$$t = A_v/(b_w*s) + 2*tf/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*tf/b_w*(f_{fe}/f_s) = 0.0075814$$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 960.00$, is the total Length of all stirrups parallel to loading (shear) direction

The term $2*tf/b_w*(f_{fe}/f_s)$ is implemented to account for FRP contribution

where $f = 2*tf/b_w$ 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.

$$N_{UD} = 4742.638$$

$$A_g = 120000.00$$

$$f'_cE = 15.00$$

$$f_{ytE} = f_{ylE} = 444.44$$

$$p_l = \text{Area}_{\text{Tot_Long_Rein}}/(b*d) = 0.03607992$$

$$b = 400.00$$

$$d = 357.00$$

$$f'_cE = 15.00$$

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

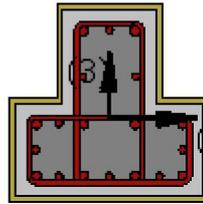
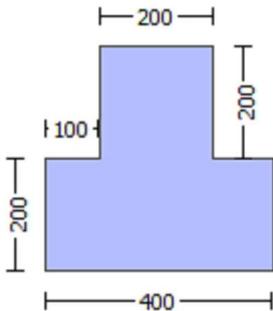
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

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, $\gamma = 0.90$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

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, $f_c = f_{c_lower_bound} = 10.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 18203.022$

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -1284.318$
Shear Force, $V_a = 0.77690092$
EDGE -B-
Bending Moment, $M_b = -853.8761$
Shear Force, $V_b = -0.77690092$
BOTH EDGES
Axial Force, $F = -4742.638$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_{t1} = 2375.044$
-Compression: $As_{c1} = 2777.168$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t2} = 2261.947$
-Compression: $As_{c2} = 829.3805$
-Middle: $As_{mid} = 2060.885$
Mean Diameter of Tension Reinforcement, $Db_{L,t} = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 144111.676$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{Co10} = 160124.085$
 $V_{Co1} = 160124.085$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.00098248$

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)
 $f'_c = 10.00$, but $f'_c^{0.5} \leq 8.3$ MPa ((2.5.3.1), ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 1284.318$
 $V_u = 0.77690092$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 4742.638$
 $A_g = 80000.00$
From ((11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$
where:
 $V_{s1} = 0.00$ is calculated for section web, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
 V_{s1} is multiplied by $Col1 = 0.00$
 $s/d = 1.1875$
 $V_{s2} = 0.00$ is calculated for section flange, with:
 $d = 160.00$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 380.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 2.375$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, 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 $(\cot \theta + \csc \theta) \sin \theta$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE). This later relation, considered as a function $V_f(\theta, a_1)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 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: $V_s + V_f \leq 134445.642$
 $b_w = 200.00$

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 $\theta = 1.3462679E-005$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.01370277$ ((4.29), Biskinis Phd))
 $M_y = 1.9917E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1653.13
From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 8.0093E+012$
factor = 0.30
 $A_g = 120000.00$
 $f_c' = 15.00$
 $N = 4742.638$
 $E_c \cdot I_g = 2.6698E+013$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 400.00$
web width, $b_w = 200.00$
flange thickness, $t = 200.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 5.8877969E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (b/d)^{2/3}) = 235.317$
 $d = 357.00$
 $y = 0.44023952$
 $A = 0.03622105$
 $B = 0.0247658$
with $p_t = 0.01583996$
 $p_c = 0.00580799$
 $p_v = 0.01443197$
 $N = 4742.638$
 $b = 400.00$
 $" = 0.12044818$
 $y_{comp} = 1.0200757E-005$
with $f_c' = 15.00$ (12.3, (ACI 440)) = 16.19674
 $f_l = 0.93147527$
 $b = b_{max} = 400.00$
 $h = h_{max} = 400.00$
 $A_g = 120000.00$
 $g = p_t + p_c + p_v = 0.03607992$
 $r_c = 40.00$
 $A_e / A_c = 0.40981737$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 18203.022$

$y = 0.43980075$

$A = 0.03597623$

$B = 0.02462466$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.43980075 < t/d$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.27567359$

$l_b = 300.00$

$l_d = 1088.244$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 24.02082$

$K_{tr} = 0.82673491$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 20.00$

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

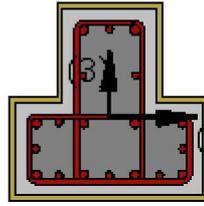
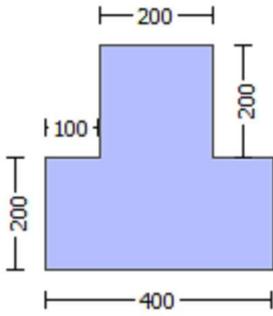
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

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, $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.27578

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 0.01054019$

EDGE -B-

Shear Force, $V_b = -0.01054019$
BOTH EDGES
Axial Force, $F = -4737.328$
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, $V_e/V_r = 0.82694402$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 162085.836$
with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 2.4313E+008$
 $\mu_{1+} = 2.4313E+008$, 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
 $\mu_{1-} = 1.2706E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 2.4313E+008$
 $\mu_{2+} = 2.4313E+008$, 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
 $\mu_{2-} = 1.2706E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 2.6161250E-005$
 $M_u = 2.4313E+008$

with full section properties:

$b = 200.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00442328$
 $N = 4737.328$

$f_c = 15.00$

$\alpha_{co} (5A.5, \text{TBDY}) = 0.002$

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.018$

$\mu_{cc} ((5.4c), \text{TBDY}) = \alpha_{se} * \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

where $f = \alpha_{f} * \rho_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.15303423$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

 $f_y = 0.15303423$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 400.00$

hmax = 400.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.01016$
bw = 200.00
effective stress from (A.35), $ff,e = 524.0792$

R = 40.00
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase = \text{Max}((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}} * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
 L_{stir} (Length of stirrups along Y) = 960.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 120000.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
 L_{stir} (Length of stirrups along X) = 960.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 120000.00

s = 380.00

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

c = confinement factor = 1.27578

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.22053887$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

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, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.22053887$

$su_2 = 0.4 * esu_{2,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,
For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $fs2 = fs = 253.4875$
with $Es2 = Es = 200000.00$
 $yv = 0.0010562$
 $shv = 0.00365026$
 $ftv = 304.185$
 $fyv = 253.4875$
 $suv = 0.00365026$
using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$
and also multiplied by the $shear_factor$ according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou, min = lb/d = 0.22053887$
 $suv = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$
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, ASCE 41-17.
with $fsv = fs = 253.4875$
with $Es = Es = 200000.00$
 $1 = Asl, ten/(b*d)*(fs1/fc) = 0.53536441$
 $2 = Asl, com/(b*d)*(fs2/fc) = 0.19630028$
 $v = Asl, mid/(b*d)*(fsv/fc) = 0.48777647$
and confined core properties:
 $b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = confinement\ factor = 1.27578$
 $1 = Asl, ten/(b*d)*(fs1/fc) = 0.83497202$
 $2 = Asl, com/(b*d)*(fs2/fc) = 0.30615641$
 $v = Asl, mid/(b*d)*(fsv/fc) = 0.76075229$
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
--->
 $cu (4.10) = 0.46564051$
 $MRC (4.17) = 2.0934E+008$
--->
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, fcc, cc , used in lieu of fc, ecu
--->
Subcase: Rupture of tension steel
--->
 $v^* < v^*, y2$ - LHS eq.(4.5) is not satisfied
--->
 $v^* < v^*, c$ - 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) = 0.55615794

M_{Ro} (4.17) = 2.4313E+008

--->

u = cu (4.2) = 2.6161250E-005

Mu = M_{Ro}

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.22053887

lb = 300.00

l_d = 1360.304

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 15.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

K_{tr} = 0.82673491

A_{tr} = Min(A_{tr_x}, A_{tr_y}) = 157.0796

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

s = 380.00

n = 20.00

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.3353763E-005

Mu = 1.2706E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00221164

N = 4737.328

fc = 15.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.018

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.018

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+ Min(fx, fy) = 0.15303423

where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.15303423

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.43111111

with Unconfined area = ((bmax-2R)^2+ (hmax-2R)^2)/3 = 51733.333

bmax = 400.00

hmax = 400.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.01016

bw = 200.00

effective stress from (A.35), $f_{f,e} = 524.0792$

$f_y = 0.15303423$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.43111111$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

c = confinement factor = 1.27578

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.22053887$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

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, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$$f_y2 = 253.4875$$

$$s_u2 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$$

$$s_u2 = 0.4 * e_{su2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2_nominal} = 0.08$,

For calculation of $e_{su2_nominal}$ and y_2 , sh_2, ft_2, f_y2 , it is considered
characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1 , sh_1, ft_1, f_y1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{s2} = f_s = 253.4875$$

$$\text{with } E_{s2} = E_s = 200000.00$$

$$y_v = 0.0010562$$

$$sh_v = 0.00365026$$

$$ft_v = 304.185$$

$$f_{y_v} = 253.4875$$

$$s_{u_v} = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.22053887$$

$$s_{u_v} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv_nominal}$ and y_v , sh_v, ft_v, f_{y_v} , it is considered
characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , sh_1, ft_1, f_y1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{sv} = f_s = 253.4875$$

$$\text{with } E_{sv} = E_s = 200000.00$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.09815014$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.26768221$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.24388823$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 19.13667$$

$$cc (5A.5, TBDY) = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$1 = A_{s1,ten}/(b*d) * (f_{s1}/f_c) = 0.1260644$$

$$2 = A_{s1,com}/(b*d) * (f_{s2}/f_c) = 0.34381201$$

$$v = A_{s1,mid}/(b*d) * (f_{sv}/f_c) = 0.31325094$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.23431248$$

$$\mu_u = M_{Rc} (4.14) = 1.2706E+008$$

$$u = s_u (4.1) = 1.3353763E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of μ_{2+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$\mu_u = 2.6161250E-005$$

$$\mu_{2+} = 2.4313E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$\alpha_{co} \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_{cu}^* = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.018$$

$$\mu_{cu} \text{ (5.4c), TBDY} = \alpha_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f_x = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00165347$$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir \text{ (Length of stirrups along Y)} = 960.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 120000.00$$

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir \text{ (Length of stirrups along X)} = 960.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y1 = 0.0010562$$

$$sh1 = 0.00365026$$

$$ft1 = 304.185$$

$$fy1 = 253.4875$$

$$su1 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/d = 0.22053887$$

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = fs = 253.4875$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0010562$$

$$sh2 = 0.00365026$$

$$ft2 = 304.185$$

$$fy2 = 253.4875$$

$$su2 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.22053887$$

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$y2, sh2,ft2,fy2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = fs = 253.4875$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0010562$$

$$shv = 0.00365026$$

$$ftv = 304.185$$

$$fyv = 253.4875$$

$$suv = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/d = 0.22053887$$

$$suv = 0.4 * esuv_nominal \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv_nominal = 0.08,$$

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.

$$yv, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fsv = fs = 253.4875$$

```

with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.53536441
2 = Asl,com/(b*d)*(fs2/fc) = 0.19630028
v = Asl,mid/(b*d)*(fsv/fc) = 0.48777647
and confined core properties:
b = 140.00
d = 327.00
d' = 13.00
fcc (5A.2, TBDY) = 19.13667
cc (5A.5, TBDY) = 0.00475778
c = confinement factor = 1.27578
1 = Asl,ten/(b*d)*(fs1/fc) = 0.83497202
2 = Asl,com/(b*d)*(fs2/fc) = 0.30615641
v = Asl,mid/(b*d)*(fsv/fc) = 0.76075229
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) = 0.46564051
MRc (4.17) = 2.0934E+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, fcc, cc, used in lieu of fc, ecu
--->
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) = 0.55615794
MRo (4.17) = 2.4313E+008
--->
u = cu (4.2) = 2.6161250E-005
Mu = MRo
-----

Calculation of ratio lb/lc
-----
Lap Length: lb/lc = 0.22053887
lb = 300.00
lc = 1360.304
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

```

db = 18.00

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

Atr = $\text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = 380.00

n = 20.00

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.3353763E-005$

$\mu_2 = 1.2706E+008$

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00221164

N = 4737.328

$f_c' = 15.00$

α (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.018$

μ_{cc} ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

where $f = \alpha f_p * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.15303423$

Expression ((15B.6), TBDY) is modified as $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.43111111$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

 $f_y = 0.15303423$

Expression ((15B.6), TBDY) is modified as $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.43111111$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

R = 40.00

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\mu_{f,5} = 0.015$

$\alpha s_e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max = 75600.00 is the confined core 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 = 0.00 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 = 33066.667 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) = 0.00165347

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00165347

Lstir (Length of stirrups along Y) = 960.00

Astir (stirrups area) = 78.53982

Asec (section area) = 120000.00

psh,y ((5.4d), TBDY) = Lstir*Astir/(Asec*s) = 0.00165347

Lstir (Length of stirrups along X) = 960.00

Astir (stirrups area) = 78.53982

Asec (section area) = 120000.00

s = 380.00

fywe = 555.55

fce = 15.00

From ((5.A5), TBDY), TBDY: cc = 0.00475778

c = confinement factor = 1.27578

y1 = 0.0010562

sh1 = 0.00365026

ft1 = 304.185

fy1 = 253.4875

su1 = 0.00365026

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/l_d = 0.22053887

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, ASCE 41-17.

with fs1 = fs = 253.4875

with Es1 = Es = 200000.00

y2 = 0.0010562

sh2 = 0.00365026

ft2 = 304.185

fy2 = 253.4875

su2 = 0.00365026

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/l_b,min = 0.22053887

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, ASCE 41-17.

with fs2 = fs = 253.4875

with Es2 = Es = 200000.00

yv = 0.0010562

shv = 0.00365026

ftv = 304.185

fyv = 253.4875

suv = 0.00365026

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/l_d = 0.22053887

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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, ASCE 41-17.

with $fsv = fs = 253.4875$

with $Esv = Es = 200000.00$

$$1 = A_{sl,ten}/(b*d) * (fs1/fc) = 0.09815014$$

$$2 = A_{sl,com}/(b*d) * (fs2/fc) = 0.26768221$$

$$v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.24388823$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 19.13667$$

$$cc (5A.5, TBDY) = 0.00475778$$

c = confinement factor = 1.27578

$$1 = A_{sl,ten}/(b*d) * (fs1/fc) = 0.1260644$$

$$2 = A_{sl,com}/(b*d) * (fs2/fc) = 0.34381201$$

$$v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.31325094$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < vs,y2$ - LHS eq.(4.5) is satisfied

$$su (4.9) = 0.23431248$$

$$\mu = MRc (4.14) = 1.2706E+008$$

$$u = su (4.1) = 1.3353763E-005$$

Calculation of ratio lb/ld

$$\text{Lap Length: } lb/ld = 0.22053887$$

$$lb = 300.00$$

$$ld = 1360.304$$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

Mean strength value of all re-bars: $fy = 555.55$

$$fc' = 15.00, \text{ but } fc'^{0.5} <= 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

$$\text{Calculation of Shear Strength } V_r = \text{Min}(V_{r1}, V_{r2}) = 196005.816$$

$$\text{Calculation of Shear Strength at edge 1, } V_{r1} = 227350.021$$

$$V_{r1} = V_{Col} ((10.3), \text{ ASCE 41-17}) = knl * V_{Col0}$$

$$V_{Col0} = 227350.021$$

$$knl = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_s + f * V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$fc' = 15.00, \text{ but } fc'^{0.5} <= 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$\mu_u = 3.21769$
 $V_u = 0.01054019$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 4737.328$
 $A_g = 80000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 320.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.1875$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 160.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 2.375$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \alpha + \cos \alpha$ is replaced with $(\cot \alpha + \cot \alpha) \sin \alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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: $V_s + V_f \leq 164661.611$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 196005.816$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$

$V_{Col0} = 196005.816$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' V_s ' is replaced by ' $V_{s+} + f^*V_f$ ' where V_f is the contribution of FRPs ((11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 23.99609$

$V_u = 0.01054019$

$d = 0.8 \cdot h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 320.00$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.1875$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 160.00$

Av = 157079.633

fy = 444.44

s = 380.00

Vs2 is multiplied by Col2 = 0.00

s/d = 2.375

Vf ((11-3)-(11.4), ACI 440) = 188111.148

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 $Vf(\alpha, \theta)$, 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: $\theta = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, 1)|, |Vf(-45, a1)|), with:

total thickness per orientation, $tf1 = NL*t/NoDir = 1.016$

dfv = d (figure 11.2, ACI 440) = 357.00

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 <= 164661.611

bw = 200.00

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, $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25*f_{sm} = 555.55$

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.27578

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 1.5456333E-009$
EDGE -B-
Shear Force, $V_b = -1.5456333E-009$
BOTH EDGES
Axial Force, $F = -4737.328$
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, $V_e/V_r = 0.55718248$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 126675.449$
with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.9001E+008$
 $\mu_{u1+} = 1.9001E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 1.9001E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.9001E+008$
 $\mu_{u2+} = 1.9001E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $\mu_{u2-} = 1.9001E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 1.7086748E-005$
 $\mu_u = 1.9001E+008$

with full section properties:

$b = 200.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00442328$
 $N = 4737.328$
 $f_c = 15.00$
 $\alpha_1(5A.5, TBDY) = 0.002$
Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \alpha_1) = 0.018$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_u = 0.018$
 $\mu_u(5.4c, TBDY) = \alpha_1 * \text{sh}_{min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$
where $f = \alpha_1 * \rho_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 0.00$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) * (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 960.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 120000.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} \text{ (Length of stirrups along X)} = 960.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y_1 = 0.0010562$$

$$sh_1 = 0.00365026$$

$$ft_1 = 304.185$$

$$fy_1 = 253.4875$$

$$su_1 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/d = 0.22053887$$

$$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1,nominal} = 0.08,$$

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = fs = 253.4875$

with $Es1 = Es = 200000.00$

$y2 = 0.0010562$

$sh2 = 0.00365026$

$ft2 = 304.185$

$fy2 = 253.4875$

$su2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo_{ou,min} = lb/lb_{,min} = 0.22053887$

$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = fs = 253.4875$

with $Es2 = Es = 200000.00$

$yv = 0.0010562$

$shv = 0.00365026$

$ftv = 304.185$

$fyv = 253.4875$

$su v = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo_{ou,min} = lb/ld = 0.22053887$

$su v = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fsv = fs = 253.4875$

with $Esv = Es = 200000.00$

$1 = Asl_{,ten}/(b*d)*(fs1/fc) = 0.29147618$

$2 = Asl_{,com}/(b*d)*(fs2/fc) = 0.29147618$

$v = Asl_{,mid}/(b*d)*(fsv/fc) = 0.6364888$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 19.13667$

$cc (5A.5, TBDY) = 0.00475778$

$c = \text{confinement factor} = 1.27578$

$1 = Asl_{,ten}/(b*d)*(fs1/fc) = 0.45459588$

$2 = Asl_{,com}/(b*d)*(fs2/fc) = 0.45459588$

$v = Asl_{,mid}/(b*d)*(fsv/fc) = 0.99268896$

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

--->

$su (4.8) = 0.40159417$

$Mu = MRc (4.15) = 1.9001E+008$

$u = su (4.1) = 1.7086748E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.22053887$

$lb = 300.00$

ld = 1360.304

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 15.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

Atr = Min(Atr_x, Atr_y) = 157.0796

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis

s = 380.00

n = 20.00

Calculation of Mu1-

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

u = 1.7086748E-005

Mu = 1.9001E+008

with full section properties:

b = 200.00

d = 357.00

d' = 43.00

v = 0.00442328

N = 4737.328

fc = 15.00

co (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.018$

we ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

where $f = \text{af} * \text{pf} * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.15303423$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\text{af} = 0.43111111$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

$f_y = 0.15303423$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\text{af} = 0.43111111$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

R = 40.00

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\text{ase} = \text{Max}(((\text{Aconf}_{\max} - \text{AnoConf}) / \text{Aconf}_{\max}) * (\text{Aconf}_{\min} / \text{Aconf}_{\max}), 0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

$c = \text{confinement factor} = 1.27578$

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = l_b/l_d = 0.22053887$

$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = l_b/l_{b,min} = 0.22053887$

$su_2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = fs = 253.4875$

with $Es_2 = Es = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$suv = 0.00365026$

using (30) in Biskinis/Fardis (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/d = 0.22053887

su = 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, ASCE 41-17.

with fsv = fs = 253.4875

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.29147618

2 = Asl,com/(b*d)*(fs2/fc) = 0.29147618

v = Asl,mid/(b*d)*(fsv/fc) = 0.6364888

and confined core properties:

b = 140.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

c = confinement factor = 1.27578

1 = Asl,ten/(b*d)*(fs1/fc) = 0.45459588

2 = Asl,com/(b*d)*(fs2/fc) = 0.45459588

v = Asl,mid/(b*d)*(fsv/fc) = 0.99268896

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) = 0.40159417

Mu = MRc (4.15) = 1.9001E+008

u = su (4.1) = 1.7086748E-005

Calculation of ratio lb/d

Lap Length: lb/d = 0.22053887

lb = 300.00

ld = 1360.304

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 15.00, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

Atr = $\text{Min}(Atr_x, Atr_y)$ = 157.0796

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = 380.00

n = 20.00

Calculation of Mu2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.7086748E-005

Mu = 1.9001E+008

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} (\text{Length of stirrups along Y}) = 960.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 120000.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} (\text{Length of stirrups along X}) = 960.00$$

$$A_{stir} (\text{stirrups area}) = 78.53982$$

$$A_{sec} (\text{section area}) = 120000.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00475778$

$c =$ confinement factor = 1.27578

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/d = 0.22053887$

$su_1 = 0.4 * esu_1,nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_1,nominal = 0.08$,

For calculation of $esu_1,nominal$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/lb,min = 0.22053887$

$su_2 = 0.4 * esu_2,nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_2,nominal = 0.08$,

For calculation of $esu_2,nominal$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = fs = 253.4875$

with $Es_2 = Es = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$su_v = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/d = 0.22053887$

$su_v = 0.4 * esuv,nominal ((5.5), TBDY) = 0.032$

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 $Min(1, 1.25 * (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fsv = fs = 253.4875$

with $Esv = Es = 200000.00$

$1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.29147618$

$2 = Asl,com / (b * d) * (fs_2 / fc) = 0.29147618$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 19.13667$

$cc (5A.5, TBDY) = 0.00475778$

$c =$ confinement factor = 1.27578

$1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.45459588$

$2 = Asl,com / (b * d) * (fs_2 / fc) = 0.45459588$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.99268896$

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

--->

$$s_u(4.8) = 0.40159417$$

$$\mu = M_{Rc}(4.15) = 1.9001E+008$$

$$u = s_u(4.1) = 1.7086748E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7086748E-005$$

$$\mu = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \mu = 0.018$$

$$\text{we ((5.4c), TB DY) } = a_s e^* s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

bmax = 400.00
hmax = 400.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.01016$
bw = 200.00
effective stress from (A.35), $ff,e = 524.0792$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00165347$

Expression ((5.4d), TBDY) for $psh_{,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
Lstir (Length of stirrups along Y) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
Lstir (Length of stirrups along X) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

s = 380.00
 $f_{ywe} = 555.55$
fce = 15.00

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

c = confinement factor = 1.27578

$y_1 = 0.0010562$
 $sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{,min} = lb/l_d = 0.22053887$

$su_1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$
 $sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{,min} = lb/l_{b,min} = 0.22053887$

$su_2 = 0.4 * esu_2_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fs_2 = fs = 253.4875$
 with $Es_2 = Es = 200000.00$
 $yv = 0.0010562$
 $shv = 0.00365026$
 $ftv = 304.185$
 $fyv = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.22053887$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $Es_v = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.29147618$
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.29147618$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$

and confined core properties:

$b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.45459588$
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.45459588$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.99268896$

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
 --->
 $su (4.8) = 0.40159417$
 $Mu = MRc (4.15) = 1.9001E+008$
 $u = su (4.1) = 1.7086748E-005$

 Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.22053887$
 $lb = 300.00$
 $ld = 1360.304$
 Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 15.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 24.02082$
 $Ktr = 0.82673491$
 $Atr = Min(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis
 $s = 380.00$

n = 20.00

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227350.021$

Calculation of Shear Strength at edge 1, $V_{r1} = 227350.021$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$

$V_{Col0} = 227350.021$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.00988804$

$V_u = 1.5456333E-009$

$d = 0.8 * h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 2.375$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.1875$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

$w_f/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a)|)$, with:

total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 357.00

$ffe ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$

$bw = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 227350.021$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$

$V_{Col0} = 227350.021$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.00525978$

$V_u = 1.5456333E-009$

$d = 0.8 \cdot h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 2.375$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.1875$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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: $V_s + V_f \leq 164661.611$

$b_w = 200.00$

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, $\gamma = 0.90$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

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, $f_c = f_{cm} = 15.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, Ecc = 100.00
 Cover Thickness, c = 25.00
 Element Length, L = 3000.00
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length lb = 300.00
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, t = 1.016
 Tensile Strength, ffu = 1055.00
 Tensile Modulus, Ef = 64828.00
 Elongation, efu = 0.01
 Number of directions, NoDir = 1
 Fiber orientations, bi: 0.00°
 Number of layers, NL = 1
 Radius of rounding corners, R = 40.00

 Stepwise Properties

Bending Moment, M = -1.1892E+007
 Shear Force, V2 = -3961.043
 Shear Force, V3 = 0.77690092
 Axial Force, F = -4742.638
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: Asl,t = 2375.044
 -Compression: Asl,c = 2777.168
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: Asl,ten = 1231.504
 -Compression: Asl,com = 1231.504
 -Middle: Asl,mid = 2689.203
 Mean Diameter of Tension Reinforcement, DbL = 17.60

 Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = \gamma + \rho u = 0.05657054$
 $u = \gamma + \rho = 0.06285615$

 - Calculation of γ -

$\gamma = (M \gamma_{Ls} / 3) / E_{eff} = 0.02085615$ ((4.29), Biskinis Phd))
 $M \gamma = 1.3657E+008$
 $L_s = M / V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3002.161
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 6.5531E+012$
 factor = 0.30
 $A_g = 120000.00$
 $f_c' = 15.00$
 $N = 4742.638$
 $E_c * I_g = 2.1844E+013$

 Calculation of Yielding Moment M_y

 Calculation of γ and M_y according to Annex 7 -

$\gamma = \text{Min}(\gamma_{ten}, \gamma_{com})$
 $\gamma_{ten} = 5.8874430E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 235.317$
 $d = 357.00$
 $\gamma = 0.44020587$

A = 0.0724421
 B = 0.04070795
 with $p_t = 0.0075814$
 $p_c = 0.01724796$
 $p_v = 0.03766391$
 N = 4742.638
 b = 200.00
 $\alpha = 0.12044818$
 $y_{comp} = 1.0162879E-005$
 with f_c^* (12.3, (ACI 440)) = 16.12972
 $f_c = 15.00$
 $f_l = 0.93147527$
 b = $b_{max} = 400.00$
 h = $h_{max} = 400.00$
 $A_g = 120000.00$
 $g = p_t + p_c + p_v = 0.07215983$
 $r_c = 40.00$
 $A_e/A_c = 0.38686758$
 Effective FRP thickness, $t_f = N L^* t \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 18203.022$
 $y = 0.43961339$
 A = 0.0719516
 B = 0.04042568
 with $E_s = 200000.00$

 Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.27567359$

$l_b = 300.00$

$l_d = 1088.244$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 24.02082$

$K_{tr} = 0.82673491$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 20.00$

 - Calculation of ρ_p -

From table 10-8: $\rho_p = 0.042$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$

shear control ratio $V_y E / V_{CoI OE} = 0.55718248$

$d = 357.00$

$s = 0.00$

$t = A_v / (b_w s) + 2 t_f / b_w (f_{fe} / f_s) = A_v L_{stir} / (A_g s) + 2 t_f / b_w (f_{fe} / f_s) = 0.0075814$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 960.00$, 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.

$NUD = 4742.638$

$A_g = 120000.00$

$f_{cE} = 15.00$
 $f_{ytE} = f_{ylE} = 444.44$
 $\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.07215983$
 $b = 200.00$
 $d = 357.00$
 $f_{cE} = 15.00$

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

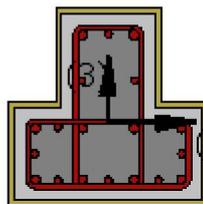
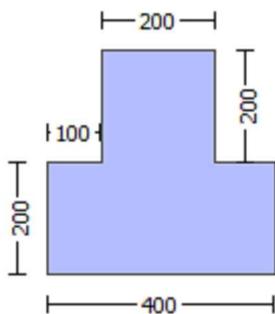
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

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, $\gamma = 0.90$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

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, $f_c = f_{c_lower_bound} = 10.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 18203.022$

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, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -1.1892E+007$

Shear Force, $V_a = -3961.043$

EDGE -B-

Bending Moment, $M_b = 1473.353$

Shear Force, $V_b = 3961.043$

BOTH EDGES

Axial Force, $F = -4742.638$

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 $V_R = \phi V_n = 167222.274$

V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 185802.527$

$V_{CoI} = 185802.527$

$k_n = 1.00$

displacement_ductility_demand = 0.13062129

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)

$f'_c = 10.00$, but $f'_c \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 1473.353$$

$$V_u = 3961.043$$

$$d = 0.8 \cdot h = 320.00$$

$$N_u = 4742.638$$

$$A_g = 80000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 0.00$$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$$d = 160.00$$

$$A_v = 157079.633$$

$$f_y = 400.00$$

$$s = 380.00$$

V_{s1} is multiplied by $Col1 = 0.00$

$$s/d = 2.375$$

$V_{s2} = 0.00$ is calculated for section flange, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 400.00$$

$$s = 380.00$$

V_{s2} is multiplied by $Col2 = 0.00$

$$s/d = 1.1875$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 188111.148$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$

$$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|), \text{ with:}$$

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$$d_{fv} = d \text{ (figure 11.2, ACI 440) } = 357.00$$

$$f_{fe} \text{ ((11-5), ACI 440) } = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 134445.642$$

$$b_w = 200.00$$

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 $\theta = 0.00027223$

$$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00208411 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 1.3657E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 \cdot L \text{ and } L_s < 2 \cdot L) = 300.00$$

$$\text{From table 10.5, ASCE 41-17: } E_{eff} = \text{factor} \cdot E_c \cdot I_g = 6.5531E+012$$

$$\text{factor} = 0.30$$

$$A_g = 120000.00$$

$$f_c' = 15.00$$

$$N = 4742.638$$

$$E_c \cdot I_g = 2.1844E+013$$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$$y = \text{Min}(y_{ten}, y_{com})$$

$$y_{ten} = 5.8874430E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 235.317$$

$d = 357.00$
 $y = 0.44020587$
 $A = 0.0724421$
 $B = 0.04070795$
 with $pt = 0.01724796$
 $pc = 0.01724796$
 $pv = 0.03766391$
 $N = 4742.638$
 $b = 200.00$
 $" = 0.12044818$
 $y_{comp} = 1.0162879E-005$
 with $fc^* (12.3, (ACI 440)) = 16.12972$
 $fc = 15.00$
 $fl = 0.93147527$
 $b = b_{max} = 400.00$
 $h = h_{max} = 400.00$
 $Ag = 120000.00$
 $g = pt + pc + pv = 0.07215983$
 $rc = 40.00$
 $Ae/Ac = 0.38686758$
 Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 18203.022$
 $y = 0.43961339$
 $A = 0.0719516$
 $B = 0.04042568$
 with $Es = 200000.00$

 Calculation of ratio lb/l_d

Lap Length: $l_d/l_{d,min} = 0.27567359$

$lb = 300.00$

$l_d = 1088.244$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$fc' = 15.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 24.02082$

$K_{tr} = 0.82673491$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 20.00$

 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

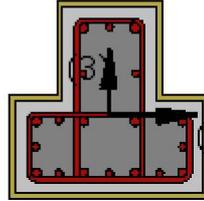
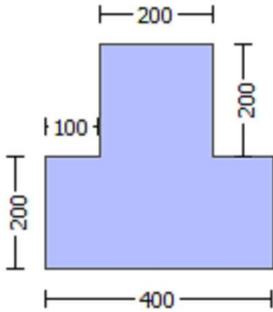
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

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, $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $E_{cc} = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.27578

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$
Number of directions, NoDir = 1
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 0.01054019$
EDGE -B-
Shear Force, $V_b = -0.01054019$
BOTH EDGES
Axial Force, $F = -4737.328$
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: $A_{sl,mid} = 2060.885$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.82694402$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 162085.836$
with

$M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.4313E+008$
 $\mu_{u1+} = 2.4313E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 1.2706E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.4313E+008$
 $\mu_{u2+} = 2.4313E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $\mu_{u2-} = 1.2706E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$\mu_u = 2.6161250E-005$
 $\mu_u = 2.4313E+008$

with full section properties:

$b = 200.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00442328$
 $N = 4737.328$
 $f_c = 15.00$
 $\alpha_{co} (5A.5, TBDY) = 0.002$
Final value of α_{cu} : $\alpha_{cu}^* = \text{shear_factor} * \text{Max}(\alpha_{cu}, \alpha_{cc}) = 0.018$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\alpha_{cu} = 0.018$
 $\alpha_{ve} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe}/f_{ce} + \text{Min}(\alpha_{fx}, \alpha_{fy}) = 0.15303423$
where $\alpha_{f} = \alpha_{f} * \rho_{f} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\alpha_{fx} = 0.15303423$
Expression ((15B.6), TBDY) is modified as $\alpha_{f} = 1 - (\text{Unconfined area})/(\text{total area})$

$$af = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.01016$$

$$bw = 200.00$$

$$\text{effective stress from (A.35), } ff,e = 524.0792$$

$$fy = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$$af = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.01016$$

$$bw = 200.00$$

$$\text{effective stress from (A.35), } ff,e = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL * t * \cos(b1) = 1.016$$

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$$psh_{\text{min}} = \text{Min}(psh_x, psh_y) = 0.00165347$$

Expression ((5.4d), TBDY) for psh_{min} has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y)} = 960.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 120000.00$$

$$psh_y \text{ ((5.4d), TBDY)} = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} \text{ (Length of stirrups along X)} = 960.00$$

$$A_{\text{stir}} \text{ (stirrups area)} = 78.53982$$

$$A_{\text{sec}} \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$fy_{we} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y1 = 0.0010562$$

$$sh1 = 0.00365026$$

$$ft1 = 304.185$$

$$fy1 = 253.4875$$

$$su1 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou_{\text{min}} = lb/ld = 0.22053887$$

$$su1 = 0.4 * esu1_{\text{nominal}} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{\text{nominal}} = 0.08,$$

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.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_1 = fs = 253.4875$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.0010562$
 $sh_2 = 0.00365026$
 $ft_2 = 304.185$
 $fy_2 = 253.4875$
 $su_2 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/lb, min = 0.22053887$
 $su_2 = 0.4 \cdot esu_2, nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_2, nominal = 0.08$,
 For calculation of $esu_2, nominal$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_2 = fs = 253.4875$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.0010562$
 $sh_v = 0.00365026$
 $ft_v = 304.185$
 $fy_v = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/d = 0.22053887$
 $suv = 0.4 \cdot esuv, nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv, nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv, nominal$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $Esv = Es = 200000.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs_1 / fc) = 0.53536441$
 $2 = Asl, com / (b \cdot d) \cdot (fs_2 / fc) = 0.19630028$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.48777647$
 and confined core properties:
 $b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = Asl, ten / (b \cdot d) \cdot (fs_1 / fc) = 0.83497202$
 $2 = Asl, com / (b \cdot d) \cdot (fs_2 / fc) = 0.30615641$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.76075229$
 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
 --->
 $cu (4.10) = 0.46564051$
 $MRC (4.17) = 2.0934E+008$

--->

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} , f_{cc} parameters of confined concrete, f_{cc} , f_{cc} used in lieu of f_c , e_{cu}

--->

Subcase: Rupture of tension steel

--->

$v^* < v^* s_y 2$ - 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

--->

$v^* < v^* c_y 2$ - LHS eq.(4.6) is not satisfied

--->

$v^* < v^* c_y 1$ - RHS eq.(4.6) is satisfied

--->

$f_{cu} (4.10) = 0.55615794$

$M_{Ro} (4.17) = 2.4313E+008$

--->

$u = f_{cu} (4.2) = 2.6161250E-005$

$\mu = M_{Ro}$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.22053887$

$l_b = 300.00$

$d = 1360.304$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 24.02082$

$K_{tr} = 0.82673491$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 20.00$

Calculation of μ_1 -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$u = 1.3353763E-005$

$\mu = 1.2706E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00221164$

$N = 4737.328$

$f_c = 15.00$

$\alpha (5A.5, \text{TBDY}) = 0.002$

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(f_{cu}, f_{cc}) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.018$

where ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

where $f = af * pf * ff_e / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.15303423$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.43111111$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $ff_e = 524.0792$

 $f_y = 0.15303423$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.43111111$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $ff_e = 524.0792$

 $R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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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$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $s = 380.00$

$fy_{we} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

$c = \text{confinement factor} = 1.27578$

$y1 = 0.0010562$

$sh1 = 0.00365026$

$ft1 = 304.185$

$fy1 = 253.4875$

$su1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.22053887

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, ASCE 41-17.

with fs1 = fs = 253.4875

with Es1 = Es = 200000.00

y2 = 0.0010562

sh2 = 0.00365026

ft2 = 304.185

fy2 = 253.4875

su2 = 0.00365026

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.22053887

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs2 = fs = 253.4875

with Es2 = Es = 200000.00

yv = 0.0010562

shv = 0.00365026

ftv = 304.185

fyv = 253.4875

suv = 0.00365026

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.22053887

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, ASCE 41-17.

with fsv = fs = 253.4875

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09815014

2 = Asl,com/(b*d)*(fs2/fc) = 0.26768221

v = Asl,mid/(b*d)*(fsv/fc) = 0.24388823

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

c = confinement factor = 1.27578

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1260644

2 = Asl,com/(b*d)*(fs2/fc) = 0.34381201

v = Asl,mid/(b*d)*(fsv/fc) = 0.31325094

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.23431248

Mu = MRc (4.14) = 1.2706E+008

u = su (4.1) = 1.3353763E-005

Calculation of ratio lb/d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$

$l_d = 1360.304$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 15.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 24.02082$

$K_{tr} = 0.82673491$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 20.00$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 2.6161250E-005$

$\mu = 2.4313E+008$

with full section properties:

$b = 200.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00442328$

$N = 4737.328$

$f_c = 15.00$

c_o (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, c_c) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu = 0.018$

we ((5.4c), TBDY) = $a_s e^* \text{sh}_{,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.15303423$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

$f_y = 0.15303423$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

$R = 40.00$

Effective FRP thickness, $t_f = N L^* t \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$$u,f = 0.015$$

$$ase = \text{Max}(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.00$$

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 = 75600.00 is the confined core 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 = 0.00 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 = 33066.667 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh,min = \text{Min}(psh,x, psh,y) = 0.00165347$$

Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh,x \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir \text{ (Length of stirrups along Y)} = 960.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 120000.00$$

$$psh,y \text{ ((5.4d), TBDY)} = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir \text{ (Length of stirrups along X)} = 960.00$$

$$Astir \text{ (stirrups area)} = 78.53982$$

$$Asec \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y1 = 0.0010562$$

$$sh1 = 0.00365026$$

$$ft1 = 304.185$$

$$fy1 = 253.4875$$

$$su1 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/l_d = 0.22053887$$

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = fs = 253.4875$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0010562$$

$$sh2 = 0.00365026$$

$$ft2 = 304.185$$

$$fy2 = 253.4875$$

$$su2 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/l_{b,min} = 0.22053887$$

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2, ft2, fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = fs = 253.4875$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0010562$$

$$shv = 0.00365026$$

$$ftv = 304.185$$

$f_{yv} = 253.4875$
 $s_{uv} = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.22053887$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5,5), TBDY) = 0.032$
 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_{yv} , 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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{sv} = f_s = 253.4875$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.53536441$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.19630028$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.48777647$
 and confined core properties:
 $b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.83497202$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.30615641$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.76075229$
 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
 --->
 $cu (4.10) = 0.46564051$
 $MRC (4.17) = 2.0934E+008$
 --->
 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} , cc , used in lieu of f_c , ecu
 --->
 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
 --->
 $*cu (4.10) = 0.55615794$

$$M_{Ro} (4.17) = 2.4313E+008$$

--->

$$u = c_u (4.2) = 2.6161250E-005$$

$$M_u = M_{Ro}$$

Calculation of ratio l_b/l_d

$$\text{Lap Length: } l_b/l_d = 0.22053887$$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of M_u

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.3353763E-005$$

$$M_u = 1.2706E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00221164$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$\text{we ((5.4c), TBDY) } = a_s e^* \text{ sh, min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

bw = 200.00
effective stress from (A.35), $f_{f,e} = 524.0792$

R = 40.00
Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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., 10.11061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
 L_{stir} (Length of stirrups along Y) = 960.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 120000.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
 L_{stir} (Length of stirrups along X) = 960.00
 A_{stir} (stirrups area) = 78.53982
 A_{sec} (section area) = 120000.00

s = 380.00
 $f_{ywe} = 555.55$
 $f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$
c = confinement factor = 1.27578

$y_1 = 0.0010562$
 $sh_1 = 0.00365026$
 $ft_1 = 304.185$
 $fy_1 = 253.4875$
 $su_1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.22053887$

$su_1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.0010562$
 $sh_2 = 0.00365026$
 $ft_2 = 304.185$
 $fy_2 = 253.4875$
 $su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.22053887$

$su_2 = 0.4 * esu2_{nominal}$ ((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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 196005.816$

Calculation of Shear Strength at edge 1, $V_{r1} = 227350.021$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$

$V_{Col0} = 227350.021$

$knl = 1$ (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).

$\lambda = 1$ (normal-weight concrete)

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 3.21769$

$\nu_u = 0.01054019$

$d = 0.8 * h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.1875$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 2.375$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$

$b_w = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 196005.816$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$

$V_{Col0} = 196005.816$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 23.99609$

$\nu_u = 0.01054019$

$d = 0.8 * h = 320.00$

Nu = 4737.328
Ag = 80000.00
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 0.00

where:

Vs1 = 0.00 is calculated for section web, with:

d = 320.00
Av = 157079.633
fy = 444.44
s = 380.00

Vs1 is multiplied by Col1 = 0.00

s/d = 1.1875

Vs2 = 0.00 is calculated for section flange, with:

d = 160.00
Av = 157079.633
fy = 444.44
s = 380.00

Vs2 is multiplied by Col2 = 0.00

s/d = 2.375

Vf ((11-3)-(11.4), ACI 440) = 188111.148

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $Vf(\theta, \alpha)$, 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: $\theta = b1 + 90^\circ = 90.00$

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) = 357.00

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 <= 164661.611

bw = 200.00

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, $\phi = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.55$

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.27578
 Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $bi: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

 Stepwise Properties

At local axis: 2
 EDGE -A-
 Shear Force, $V_a = 1.5456333E-009$
 EDGE -B-
 Shear Force, $V_b = -1.5456333E-009$
 BOTH EDGES
 Axial Force, $F = -4737.328$
 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: $As_{l,ten} = 1231.504$
 -Compression: $As_{l,com} = 1231.504$
 -Middle: $As_{l,mid} = 2689.203$

 Calculation of Shear Capacity ratio , $V_e/V_r = 0.55718248$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 126675.449$
 with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 1.9001E+008$
 $Mu_{1+} = 1.9001E+008$, 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
 $Mu_{1-} = 1.9001E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 1.9001E+008$
 $Mu_{2+} = 1.9001E+008$, 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
 $Mu_{2-} = 1.9001E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
 direction which is defined for the the static loading combination

 Calculation of Mu_{1+}

 Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.7086748E-005$
 $M_u = 1.9001E+008$

 with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e ((5.4c), TBDY) = a_s e^* s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh, \min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

Expression ((5.4d), TBDY) for $p_{sh, \min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} (\text{Length of stirrups along Y}) = 960.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 120000.00$$

$$p_{sh,y} ((5.4d), TBDY) = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} (\text{Length of stirrups along X}) = 960.00$$

$$A_{\text{stir}} (\text{stirrups area}) = 78.53982$$

$$A_{\text{sec}} (\text{section area}) = 120000.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

From ((5.A.5), TBDY), TBDY: $cc = 0.00475778$

$c =$ confinement factor = 1.27578

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/ld = 0.22053887$

$su_1 = 0.4 * esu_1,nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_1,nominal = 0.08$,

For calculation of $esu_1,nominal$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/lb,min = 0.22053887$

$su_2 = 0.4 * esu_2,nominal ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $fs_2 = fs = 253.4875$

with $Es_2 = Es = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$su_v = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lou,min = lb/ld = 0.22053887$

$su_v = 0.4 * esuv,nominal ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $fsv = fs = 253.4875$

with $Esv = Es = 200000.00$

$1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.29147618$

$2 = Asl,com / (b * d) * (fs_2 / fc) = 0.29147618$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 19.13667$

$cc (5A.5, TBDY) = 0.00475778$

$c =$ confinement factor = 1.27578

$1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.45459588$

$2 = Asl,com / (b * d) * (fs_2 / fc) = 0.45459588$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.99268896$

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

--->

$$s_u(4.8) = 0.40159417$$

$$\mu = M_{Rc}(4.15) = 1.9001E+008$$

$$u = s_u(4.1) = 1.7086748E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7086748E-005$$

$$\mu = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } \mu = 0.018$$

$$\text{we ((5.4c), TB DY) } = a_s e^* s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TB DY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

bmax = 400.00
hmax = 400.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.01016$
bw = 200.00
effective stress from (A.35), $ff,e = 524.0792$

R = 40.00
Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh_{,min} = \text{Min}(psh_x, psh_y) = 0.00165347$

Expression ((5.4d), TBDY) for $psh_{,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
Lstir (Length of stirrups along Y) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

$psh_y \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$
Lstir (Length of stirrups along X) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

s = 380.00
 $f_{ywe} = 555.55$
fce = 15.00

From ((5.A5), TBDY), TBDY: cc = 0.00475778

c = confinement factor = 1.27578

$y_1 = 0.0010562$
 $sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{,min} = lb/l_d = 0.22053887$

$su_1 = 0.4 * esu_{1,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$
 $sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{,min} = lb/l_{b,min} = 0.22053887$

$su_2 = 0.4 * esu_2_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fs_2 = fs = 253.4875$
 with $Es_2 = Es = 200000.00$
 $yv = 0.0010562$
 $shv = 0.00365026$
 $ftv = 304.185$
 $fyv = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.22053887$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $Es_v = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.29147618$
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.29147618$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$

and confined core properties:

$b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.45459588$
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.45459588$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.99268896$

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

$su (4.8) = 0.40159417$

$Mu = MRc (4.15) = 1.9001E+008$

$u = su (4.1) = 1.7086748E-005$

 Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.22053887$

$lb = 300.00$

$ld = 1360.304$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars: $fy = 555.55$

$fc' = 15.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 24.02082$

$Ktr = 0.82673491$

$Atr = Min(Atr_x, Atr_y) = 157.0796$

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

n = 20.00

Calculation of Mu2+

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$u = 1.7086748E-005$

$Mu = 1.9001E+008$

with full section properties:

b = 200.00

d = 357.00

d' = 43.00

v = 0.00442328

N = 4737.328

$f_c = 15.00$

ϕ_o (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u = \text{shear_factor} * \text{Max}(\phi_u, \phi_o) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.018$

ϕ_{we} ((5.4c), TBDY) = $\text{ase} * \text{sh}_{,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.15303423$

where $\phi = \text{af} * \text{pf} * \text{ffe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.15303423$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\text{af} = 0.43111111$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 51733.333$

$b_{\text{max}} = 400.00$

$h_{\text{max}} = 400.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $\text{ffe} = 524.0792$

$\phi_y = 0.15303423$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\text{af} = 0.43111111$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 0.00$

$b_{\text{max}} = 400.00$

$h_{\text{max}} = 400.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $\text{ffe} = 524.0792$

R = 40.00

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\text{ase} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$\text{psh}_{,\text{min}} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.00165347$

Expression ((5.4d), TBDY) for $\text{psh}_{,\text{min}}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir (\text{Length of stirrups along } Y) = 960.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 120000.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir (\text{Length of stirrups along } X) = 960.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 120000.00$$

$$s = 380.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

$$\text{From } ((5.A5), TBDY), TBDY: cc = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y1 = 0.0010562$$

$$sh1 = 0.00365026$$

$$ft1 = 304.185$$

$$fy1 = 253.4875$$

$$su1 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.22053887$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = fs = 253.4875$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0010562$$

$$sh2 = 0.00365026$$

$$ft2 = 304.185$$

$$fy2 = 253.4875$$

$$su2 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.22053887$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$y2, sh2,ft2,fy2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = fs = 253.4875$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0010562$$

$$shv = 0.00365026$$

$$ftv = 304.185$$

$$fyv = 253.4875$$

$$suv = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.22053887$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv_nominal = 0.08,$$

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.

$$yv, shv,ftv,fyv, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fsv = fs = 253.4875$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.29147618$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.29147618$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$$

and confined core properties:

$$b = 140.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 19.13667$$

$$cc (5A.5, TBDY) = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.45459588$$

$$2 = A_{s2,com}/(b*d)*(f_{s2}/f_c) = 0.45459588$$

$$v = A_{s,mid}/(b*d)*(f_{sv}/f_c) = 0.99268896$$

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

--->

$$s_u (4.8) = 0.40159417$$

$$M_u = M_{Rc} (4.15) = 1.9001E+008$$

$$u = s_u (4.1) = 1.7086748E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of M_u

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7086748E-005$$

$$M_u = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$\text{we ((5.4c), TBDY) } = a_s * \text{sh}_{, \min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_s * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$
 $a_f = 0.43111111$

with Unconfined area = $((b_{\max}-2R)^2 + (h_{\max}-2R)^2)/3 = 51733.333$

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

$f_y = 0.15303423$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$a_f = 0.43111111$

with Unconfined area = $((b_{\max}-2R)^2 + (h_{\max}-2R)^2)/3 = 0.00$

$b_{\max} = 400.00$

$h_{\max} = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.01016$

$b_w = 200.00$

effective stress from (A.35), $f_{f,e} = 524.0792$

$R = 40.00$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}})/A_{\text{conf,max}}) \cdot (A_{\text{conf,min}}/A_{\text{conf,max}}), 0) = 0.00$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{\text{stir}} \cdot A_{\text{stir}} / (A_{\text{sec}} \cdot s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{\text{stir}} \cdot A_{\text{stir}} / (A_{\text{sec}} \cdot s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00475778$

$c = \text{confinement factor} = 1.27578$

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with $\text{Shear_factor} = 1.00$

$l_o/l_{o,min} = l_b/l_d = 0.22053887$

$su_1 = 0.4 \cdot \text{esu1_nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $\text{esu1_nominal} = 0.08$,

For calculation of esu1_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, ASCE 41-17.

with $f_{s1} = f_s = 253.4875$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $f_{s2} = f_s = 253.4875$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$su_v = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.22053887$

$su_v = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $f_{sv} = f_s = 253.4875$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.29147618$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.29147618$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.6364888$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 19.13667$

$cc (5A.5, TBDY) = 0.00475778$

c = confinement factor = 1.27578

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.45459588$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.45459588$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.99268896$

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

$su (4.8) = 0.40159417$

$Mu = MRc (4.15) = 1.9001E+008$

u = $su (4.1) = 1.7086748E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$

$l_d = 1360.304$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f'_c = 15.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 227350.021$

Calculation of Shear Strength at edge 1, $V_{r1} = 227350.021$

$$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$$

$$V_{Col0} = 227350.021$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$f'_c = 15.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 2.00$$

$$\mu_u = 0.00988804$$

$$V_u = 1.5456333E-009$$

$$d = 0.8 * h = 320.00$$

$$N_u = 4737.328$$

$$A_g = 80000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 0.00$$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$$d = 160.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s1} is multiplied by $Col1 = 0.00$

$$s/d = 2.375$$

$V_{s2} = 0.00$ is calculated for section flange, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 380.00$$

V_{s2} is multiplied by $Col2 = 0.00$

$$s/d = 1.1875$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 188111.148$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \theta = 45^\circ + 90^\circ = 135^\circ$$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 357.00$$

$$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$
 $bw = 200.00$

Calculation of Shear Strength at edge 2, $V_r2 = 227350.021$
 $V_r2 = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 227350.021$
 $knl = 1$ (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)
 $fc' = 15.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.00525978$

$V_u = 1.5456333E-009$

$d = 0.8 * h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 2.375$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.1875$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, 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: $\alpha = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 357.00

$ffe ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$

$bw = 200.00$

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, $\phi = 0.90$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
 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, $f_c = f_{cm} = 15.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 18203.022$
 Steel Elasticity, $E_s = 200000.00$
 Max Height, $H_{max} = 400.00$
 Min Height, $H_{min} = 200.00$
 Max Width, $W_{max} = 400.00$
 Min Width, $W_{min} = 200.00$
 Eccentricity, $E_{cc} = 100.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i = 0.00^\circ$
 Number of layers, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -853.8761$
 Shear Force, $V_2 = 3961.043$
 Shear Force, $V_3 = -0.77690092$
 Axial Force, $F = -4742.638$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl} = 0.00$
 -Compression: $A_{slc} = 5152.212$
 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 $u_{,R} = \phi \cdot u = 0.04562592$
 $u = y + p = 0.05069546$

- Calculation of y -

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00869546$ ((4.29), Biskinis Phd)
 $M_y = 1.9010E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1099.08
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 8.0093E+012$
 factor = 0.30
 $A_g = 120000.00$
 $f_c' = 15.00$
 $N = 4742.638$

$$E_c \cdot I_g = 2.6698E+013$$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to Annex 7 -

$$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$$

$$y_{\text{ten}} = 6.8135163E-006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 235.317$$

$$d = 357.00$$

$$y = 0.51629147$$

$$A = 0.0724421$$

$$B = 0.04953159$$

$$\text{with } p_t = 0.0075814$$

$$p_c = 0.01161597$$

$$p_v = 0.02886393$$

$$N = 4742.638$$

$$b = 200.00$$

$$" = 0.12044818$$

$$y_{\text{comp}} = 8.6576116E-006$$

$$\text{with } f_c^* (12.3, (\text{ACI 440})) = 16.12972$$

$$f_c = 15.00$$

$$f_l = 0.93147527$$

$$b = b_{\text{max}} = 400.00$$

$$h = h_{\text{max}} = 400.00$$

$$A_g = 120000.00$$

$$g = p_t + p_c + p_v = 0.07215983$$

$$r_c = 40.00$$

$$A_e/A_c = 0.38686758$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cdot \text{Cos}(b_1) = 1.016$$

$$\text{effective strain from (12.5) and (12.12), } \epsilon_{fe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 18203.022$$

$$y = 0.51604736$$

$$A = 0.0719516$$

$$B = 0.04924932$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio l_b/d

$$\text{Lap Length: } l_d/d, \text{min} = 0.27567359$$

$$l_b = 300.00$$

$$l_d = 1088.244$$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 444.44$$

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

- Calculation of ρ_p -

From table 10-8: $\rho_p = 0.042$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$

shear control ratio $V_{yE}/V_{CoI0E} = 0.82694402$

$d = 357.00$

$s = 0.00$

$t = A_v/(b_w*s) + 2*t_f/b_w*(f_{fe}/f_s) = A_v*L_{stir}/(A_g*s) + 2*t_f/b_w*(f_{fe}/f_s) = 0.0075814$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 960.00$, 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.

$NUD = 4742.638$

$A_g = 120000.00$

$f_{cE} = 15.00$

$f_{ytE} = f_{ylE} = 444.44$

$\rho_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.07215983$

$b = 200.00$

$d = 357.00$

$f_{cE} = 15.00$

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

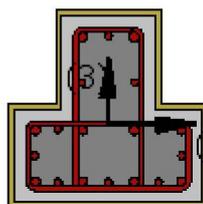
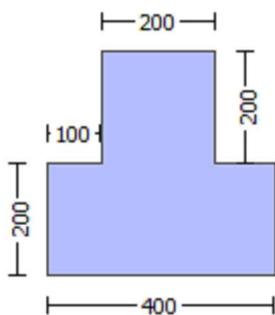
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

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, $\gamma = 0.90$
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.
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, $f_c = f_{c_lower_bound} = 10.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 18203.022$
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, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Existing material: Concrete Strength, $f_c = f_{cm} = 15.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

Max Height, $H_{max} = 400.00$
Min Height, $H_{min} = 200.00$
Max Width, $W_{max} = 400.00$
Min Width, $W_{min} = 200.00$
Eccentricity, $Ecc = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -1284.318$
Shear Force, $V_a = 0.77690092$
EDGE -B-
Bending Moment, $M_b = -853.8761$
Shear Force, $V_b = -0.77690092$
BOTH EDGES
Axial Force, $F = -4742.638$
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, $Db_{L,ten} = 17.77778$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 147915.927$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI} = 164351.03$
 $V_{CoI} = 164351.03$
 $k_n = 1.00$
 $displacement_ductility_demand = 3.6025723E-005$

NOTE: In expression (10-3) 'Vs' is replaced by ' $\phi V_s + \phi V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 $f_c' = 10.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 3.43462$

$\mu_u = 853.8761$

$V_u = 0.77690092$

$d = 0.8 \cdot h = 320.00$

$N_u = 4742.638$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.1875$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 400.00$

$s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 2.375$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$\phi = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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: $V_s + V_f \leq 134445.642$

$b_w = 200.00$

$displacement_ductility_demand$ is calculated as ϕ / y

- Calculation of ϕ / y for END B -

for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 3.1326036E-007$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00869546$ ((4.29), Biskinis Phd)

$M_y = 1.9010E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1099.08

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 8.0093E+012$

factor = 0.30

$A_g = 120000.00$

$f_c' = 15.00$
 $N = 4742.638$
 $E_c \cdot I_g = 2.6698E+013$

Calculation of Yielding Moment M_y

Calculation of V_y and M_y according to Annex 7 -

 $y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 6.8135163E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 235.317$
 $d = 357.00$
 $y = 0.51629147$
 $A = 0.0724421$
 $B = 0.04953159$
with $pt = 0.03167993$
 $pc = 0.01161597$
 $pv = 0.02886393$
 $N = 4742.638$
 $b = 200.00$
 $" = 0.12044818$
 $y_{\text{comp}} = 8.6576116E-006$
with $f_c' (12.3, (ACI 440)) = 16.12972$
 $f_c = 15.00$
 $fl = 0.93147527$
 $b = b_{\text{max}} = 400.00$
 $h = h_{\text{max}} = 400.00$
 $A_g = 120000.00$
 $g = pt + pc + pv = 0.07215983$
 $rc = 40.00$
 $A_e/A_c = 0.38686758$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 18203.022$
 $y = 0.51604736$
 $A = 0.0719516$
 $B = 0.04924932$
with $E_s = 200000.00$

Calculation of ratio l_b/d

Lap Length: $l_d/d, \text{min} = 0.27567359$

$l_b = 300.00$

$l_d = 1088.244$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 15.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 24.02082$

$K_{tr} = 0.82673491$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 20.00$

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

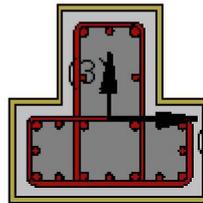
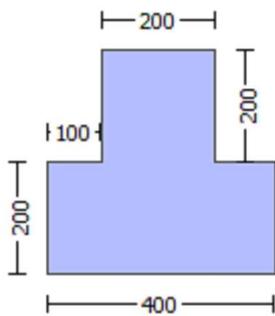
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

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, $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 15.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 18203.022$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

Max Height, $H_{max} = 400.00$

Min Height, $H_{min} = 200.00$

Max Width, $W_{max} = 400.00$

Min Width, $W_{min} = 200.00$

Eccentricity, $Ecc = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.27578

Element Length, L = 3000.00
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length lo = 300.00
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, f_{fu} = 1055.00
Tensile Modulus, E_f = 64828.00
Elongation, e_{fu} = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, V_a = 0.01054019
EDGE -B-
Shear Force, V_b = -0.01054019
BOTH EDGES
Axial Force, F = -4737.328
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_{sl,ten} = 2261.947
-Compression: A_{sl,com} = 829.3805
-Middle: A_{sl,mid} = 2060.885

Calculation of Shear Capacity ratio , $V_e/V_r = 0.82694402$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 162085.836$
with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.4313E+008$
Mu₁₊ = 2.4313E+008, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
Mu₁₋ = 1.2706E+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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.4313E+008$
Mu₂₊ = 2.4313E+008, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination
Mu₂₋ = 1.2706E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of Mu₁₊

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 2.6161250E-005$$

$$Mu = 2.4313E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e(5.4c, TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 960.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 120000.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} \text{ (Length of stirrups along X)} = 960.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$y1 = 0.0010562$
 $sh1 = 0.00365026$
 $ft1 = 304.185$
 $fy1 = 253.4875$
 $su1 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/d = 0.22053887$
 $su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fs1 = fs = 253.4875$
 with $Es1 = Es = 200000.00$

$y2 = 0.0010562$
 $sh2 = 0.00365026$
 $ft2 = 304.185$
 $fy2 = 253.4875$
 $su2 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.22053887$
 $su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2,ft2,fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs2 = fs = 253.4875$
 with $Es2 = Es = 200000.00$

$yv = 0.0010562$
 $shv = 0.00365026$
 $ftv = 304.185$
 $fyv = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/d = 0.22053887$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $Esv = Es = 200000.00$

$1 = Asl,ten/(b*d)*(fs1/fc) = 0.53536441$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.19630028$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.48777647$

and confined core properties:

$b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.83497202$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.30615641$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.76075229$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < vs,y2$ - 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

---->

ϕ_{cu} (4.10) = 0.46564051

MRC (4.17) = 2.0934E+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 $b*d$
- f_{cc} , ϕ_{cc} parameters of confined concrete, f_{cc} , ϕ_{cc} , used in lieu of f_c , ϕ_{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

---->

ϕ^*_{cu} (4.10) = 0.55615794

MRO (4.17) = 2.4313E+008

---->

$u = \phi_{cu}$ (4.2) = 2.6161250E-005

$M_u = M_{Ro}$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$

$l_d = 1360.304$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\lambda = 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 15.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 24.02082$

$K_{tr} = 0.82673491$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = 380.00$

$n = 20.00$

Calculation of M_{u1} -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.3353763E-005$$

$$\mu = 1.2706E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00221164$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$\omega (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.018$$

$$\phi_{we} \text{ ((5.4c), TBDY) } = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.15303423$$

where $\phi = a_f * \phi_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$\phi_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 0.00$$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{\text{conf,max}} - A_{\text{noConf}}) / A_{\text{conf,max}}) * (A_{\text{conf,min}} / A_{\text{conf,max}}), 0) = 0.00$$

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.

$A_{\text{conf,max}} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{\text{conf,min}} = 0.00$ 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.

$A_{\text{noConf}} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$\phi_{sh, \min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.00165347$$

Expression ((5.4d), TBDY) for $\phi_{sh, \min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\phi_{sh,x} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} \text{ (Length of stirrups along Y) } = 960.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

$$A_{\text{sec}} \text{ (section area) } = 120000.00$$

$$\phi_{sh,y} \text{ ((5.4d), TBDY) } = L_{\text{stir}} * A_{\text{stir}} / (A_{\text{sec}} * s) = 0.00165347$$

$$L_{\text{stir}} \text{ (Length of stirrups along X) } = 960.00$$

$$A_{\text{stir}} \text{ (stirrups area) } = 78.53982$$

Asec (section area) = 120000.00

s = 380.00

fywe = 555.55

fce = 15.00

From ((5.A5), TBDY), TBDY: cc = 0.00475778

c = confinement factor = 1.27578

y1 = 0.0010562

sh1 = 0.00365026

ft1 = 304.185

fy1 = 253.4875

su1 = 0.00365026

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.22053887

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE 41-17.

with fs1 = fs = 253.4875

with Es1 = Es = 200000.00

y2 = 0.0010562

sh2 = 0.00365026

ft2 = 304.185

fy2 = 253.4875

su2 = 0.00365026

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.22053887

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE 41-17.

with fs2 = fs = 253.4875

with Es2 = Es = 200000.00

yv = 0.0010562

shv = 0.00365026

ftv = 304.185

fyv = 253.4875

suv = 0.00365026

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.22053887

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 $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE 41-17.

with fsv = fs = 253.4875

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09815014

2 = Asl,com/(b*d)*(fs2/fc) = 0.26768221

v = Asl,mid/(b*d)*(fsv/fc) = 0.24388823

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

c = confinement factor = 1.27578

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1260644

$$2 = A_{sl,com}/(b*d)*(f_s2/f_c) = 0.34381201$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.31325094$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

$$s_u(4.9) = 0.23431248$$

$$M_u = M_{Rc}(4.14) = 1.2706E+008$$

$$u = s_u(4.1) = 1.3353763E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of M_u2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 2.6161250E-005$$

$$M_u = 2.4313E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o(5A.5, TBDY) = 0.002$$

Final value of c_u : $c_u^* = \text{shear_factor} * \max(c_u, c_c) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.018$

$$w_e((5.4c), TBDY) = a_{se} * s_{h, \min} * f_{ywe}/f_{ce} + \min(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.43111111$$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 51733.333$

$$b_{\max} = 400.00$$

$$h_{\max} = 400.00$$

From EC8 A4.4.3(6), $p_f = 2t_f/b_w = 0.01016$

$$b_w = 200.00$$

effective stress from (A.35), $f_{fe} = 524.0792$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $ff,e = 524.0792$

$R = 40.00$

Effective FRP thickness, $tf = NL*t*Cos(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max}) * (A_{conf,min}/A_{conf,max}), 0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b^2/6$ as defined at (A.2).

$psh_{,min} = \text{Min}(psh_{,x}, psh_{,y}) = 0.00165347$

Expression ((5.4d), TBDY) for $psh_{,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$psh_{,y}$ ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

c = confinement factor = 1.27578

$y1 = 0.0010562$

$sh1 = 0.00365026$

$ft1 = 304.185$

$fy1 = 253.4875$

$su1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_0/l_{ou,min} = l_b/l_d = 0.22053887$

$su1 = 0.4 * esu1_{nominal}$ ((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, ASCE 41-17.

with $fs1 = fs = 253.4875$

with $Es1 = Es = 200000.00$

$y2 = 0.0010562$

$sh2 = 0.00365026$

$ft2 = 304.185$

$fy2 = 253.4875$

$su2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
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, ASCE 41-17.
with $fs_2 = fs = 253.4875$
with $Es_2 = Es = 200000.00$
 $y_v = 0.0010562$
 $sh_v = 0.00365026$
 $ft_v = 304.185$
 $fy_v = 253.4875$
 $suv = 0.00365026$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.22053887$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
considering characteristic value $fsy_v = fs_v/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsy_v = fs_v/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
with $fs_v = fs = 253.4875$
with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.53536441$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.19630028$
 $v = A_{sl,mid}/(b*d) * (fs_v/f_c) = 0.48777647$
and confined core properties:
 $b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.83497202$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.30615641$
 $v = A_{sl,mid}/(b*d) * (fs_v/f_c) = 0.76075229$
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
---->
 $c_u (4.10) = 0.46564051$
 $M_{Rc} (4.17) = 2.0934E+008$
---->
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, 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) = 0.55615794

MRo (4.17) = 2.4313E+008

--->

u = cu (4.2) = 2.6161250E-005

Mu = MRo

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.22053887

lb = 300.00

l_d = 1360.304

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 15.00, but $fc'^{0.5} < 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

Atr = Min(Atr_x, Atr_y) = 157.0796

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = 380.00

n = 20.00

Calculation of Mu₂-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.3353763E-005

Mu = 1.2706E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00221164

N = 4737.328

fc = 15.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.018$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.018

we ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

f_x = 0.15303423

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

af = 0.43111111

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 51733.333$

bmax = 400.00
hmax = 400.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.01016$
bw = 200.00
effective stress from (A.35), $ff,e = 524.0792$

fy = 0.15303423
Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$
af = 0.43111111
with Unconfined area = $((bmax-2R)^2 + (hmax-2R)^2)/3 = 0.00$
bmax = 400.00
hmax = 400.00
From EC8 A 4.4.3(6), $pf = 2tf/bw = 0.01016$
bw = 200.00
effective stress from (A.35), $ff,e = 524.0792$

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 = $Max(((Aconf,max - AnoConf)/Aconf,max) * (Aconf,min/Aconf,max), 0) = 0.00$
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 = 75600.00 is the confined core 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 = 0.00 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 = 33066.667 is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).
psh,min = $Min(psh,x, psh,y) = 0.00165347$
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00165347$
Lstir (Length of stirrups along Y) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

psh,y ((5.4d), TBDY) = $Lstir * Astir / (Asec * s) = 0.00165347$
Lstir (Length of stirrups along X) = 960.00
Astir (stirrups area) = 78.53982
Asec (section area) = 120000.00

s = 380.00
fywe = 555.55
fce = 15.00
From ((5.A5), TBDY), TBDY: $cc = 0.00475778$
c = confinement factor = 1.27578
y1 = 0.0010562
sh1 = 0.00365026
ft1 = 304.185
fy1 = 253.4875
su1 = 0.00365026
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
lo/lou,min = $lb/d = 0.22053887$
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, ASCE 41-17.
with $fs1 = fs = 253.4875$

with $E_{s1} = E_s = 200000.00$
 $y_2 = 0.0010562$
 $sh_2 = 0.00365026$
 $ft_2 = 304.185$
 $fy_2 = 253.4875$
 $su_2 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_0/l_{ou,min} = l_b/l_{b,min} = 0.22053887$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fs_2 = fs = 253.4875$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.0010562$
 $sh_v = 0.00365026$
 $ft_v = 304.185$
 $fy_v = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_0/l_{ou,min} = l_b/l_d = 0.22053887$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.09815014$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.26768221$
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.24388823$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 19.13667$
 $cc (5A.5, TBDY) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.1260644$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.34381201$
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.31325094$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_s, y_2$ - LHS eq.(4.5) is satisfied

---->

$su (4.9) = 0.23431248$
 $M_u = MR_c (4.14) = 1.2706E+008$
 $u = su (4.1) = 1.3353763E-005$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$
 $l_d = 1360.304$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 18.00$

Mean strength value of all re-bars: $fy = 555.55$

$fc' = 15.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 24.02082$
 $Ktr = 0.82673491$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis
 $s = 380.00$
 $n = 20.00$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 196005.816$

Calculation of Shear Strength at edge 1, $V_{r1} = 227350.021$
 $V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = knl * V_{Col0}$
 $V_{Col0} = 227350.021$
 $knl = 1$ (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)
 $fc' = 15.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 3.21769$

$V_u = 0.01054019$

$d = 0.8 * h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $Col1 = 0.00$

$s/d = 1.1875$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 2.375$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 188111.148$

$f = 0.95$, 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 $V_f(\alpha, a_i)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 164661.611$

$b_w = 200.00$

 Calculation of Shear Strength at edge 2, $V_{r2} = 196005.816$

$$Vr2 = VCol \text{ ((10.3), ASCE 41-17)} = knl * VCol0$$

$$VCol0 = 196005.816$$

$$knl = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) 'Vs' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

$$fc' = 15.00, \text{ but } fc^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$Mu = 23.99609$$

$$Vu = 0.01054019$$

$$d = 0.8 * h = 320.00$$

$$Nu = 4737.328$$

$$Ag = 80000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } Vs = Vs1 + Vs2 = 0.00$$

where:

Vs1 = 0.00 is calculated for section web, with:

$$d = 320.00$$

$$Av = 157079.633$$

$$fy = 444.44$$

$$s = 380.00$$

Vs1 is multiplied by Col1 = 0.00

$$s/d = 1.1875$$

Vs2 = 0.00 is calculated for section flange, with:

$$d = 160.00$$

$$Av = 157079.633$$

$$fy = 444.44$$

$$s = 380.00$$

Vs2 is multiplied by Col2 = 0.00

$$s/d = 2.375$$

$$Vf \text{ ((11-3)-(11.4), ACI 440)} = 188111.148$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

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.

$$\text{orientation 1: } \alpha = b1 + 90^\circ = 90.00$$

$$Vf = \text{Min}(|Vf(45, \alpha)|, |Vf(-45, \alpha)|), \text{ with:}$$

$$\text{total thickness per orientation, } tf1 = NL * t / NoDir = 1.016$$

$$dfv = d \text{ (figure 11.2, ACI 440)} = 357.00$$

$$ffe \text{ ((11-5), ACI 440)} = 259.312$$

$$Ef = 64828.00$$

$$fe = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } fu = 0.01$$

$$\text{From (11-11), ACI 440: } Vs + Vf \leq 164661.611$$

$$bw = 200.00$$

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, $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Existing material of Primary Member: Concrete Strength, $fc = fcm = 15.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 18203.022$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

Max Height, $H_{max} = 400.00$
Min Height, $H_{min} = 200.00$
Max Width, $W_{max} = 400.00$
Min Width, $W_{min} = 200.00$
Eccentricity, $Ecc = 100.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.27578
Element Length, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 1.5456333E-009$
EDGE -B-
Shear Force, $V_b = -1.5456333E-009$
BOTH EDGES
Axial Force, $F = -4737.328$
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: $A_{sl,mid} = 2689.203$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.55718248$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 126675.449$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.9001E+008$
 $M_{u1+} = 1.9001E+008$, 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
 $M_{u1-} = 1.9001E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.9001E+008$
 $M_{u2+} = 1.9001E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination

Mu₂₋ = 1.9001E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu₁₊

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.7086748E-005$$

$$Mu = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2) / 3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2) / 3 = 0.00$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh,x ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir (\text{Length of stirrups along } Y) = 960.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 120000.00$$

$$psh,y ((5.4d), TBDY) = Lstir * Astir / (Asec * s) = 0.00165347$$

$$Lstir (\text{Length of stirrups along } X) = 960.00$$

$$Astir (\text{stirrups area}) = 78.53982$$

$$Asec (\text{section area}) = 120000.00$$

$$s = 380.00$$

$$fywe = 555.55$$

$$fce = 15.00$$

$$\text{From } ((5.A.5), TBDY), TBDY: cc = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$y1 = 0.0010562$$

$$sh1 = 0.00365026$$

$$ft1 = 304.185$$

$$fy1 = 253.4875$$

$$su1 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.22053887$$

$$su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1,ft1,fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = fs = 253.4875$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.0010562$$

$$sh2 = 0.00365026$$

$$ft2 = 304.185$$

$$fy2 = 253.4875$$

$$su2 = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.22053887$$

$$su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$y2, sh2,ft2,fy2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = fs = 253.4875$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.0010562$$

$$shv = 0.00365026$$

$$ftv = 304.185$$

$$fyv = 253.4875$$

$$suv = 0.00365026$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.22053887$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv_nominal = 0.08,$$

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.

$$yv, shv,ftv,fyv, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fsv = fs = 253.4875$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.29147618$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.29147618$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$$

and confined core properties:

$$b = 140.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 19.13667$$

$$cc (5A.5, TBDY) = 0.00475778$$

$$c = \text{confinement factor} = 1.27578$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.45459588$$

$$2 = A_{s2,com}/(b*d)*(f_{s2}/f_c) = 0.45459588$$

$$v = A_{s,mid}/(b*d)*(f_{sv}/f_c) = 0.99268896$$

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

--->

$$s_u (4.8) = 0.40159417$$

$$M_u = M_{Rc} (4.15) = 1.9001E+008$$

$$u = s_u (4.1) = 1.7086748E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.22053887$

$$l_b = 300.00$$

$$l_d = 1360.304$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of M_u1 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.7086748E-005$$

$$M_u = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$\text{we ((5.4c), TBDY) } = a_s e^* s_{h, \min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$
 $af = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 51733.333$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $ff,e = 524.0792$

$f_y = 0.15303423$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.43111111$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 0.00$

$b_{max} = 400.00$

$h_{max} = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.01016$

$bw = 200.00$

effective stress from (A.35), $ff,e = 524.0792$

$R = 40.00$

Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase = \text{Max}(((A_{conf,max}-A_{noConf})/A_{conf,max})*(A_{conf,min}/A_{conf,max}),0) = 0.00$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$p_{sh,y}$ ((5.4d), TBDY) = $L_{stir}*A_{stir}/(A_{sec}*s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

$s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

c = confinement factor = 1.27578

$y1 = 0.0010562$

$sh1 = 0.00365026$

$ft1 = 304.185$

$fy1 = 253.4875$

$su1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/d = 0.22053887$

$su1 = 0.4*esu1_{nominal}$ ((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 $f_{sy1} = f_{s1}/1.2$, 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, ASCE 41-17.

with $f_{s1} = f_s = 253.4875$

with $E_{s1} = E_s = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $f_{s2} = f_s = 253.4875$

with $E_{s2} = E_s = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$su_v = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.22053887$

$su_v = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

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, ASCE 41-17.

with $f_{sv} = f_s = 253.4875$

with $E_{sv} = E_s = 200000.00$

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.29147618$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.29147618$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.6364888$

and confined core properties:

$b = 140.00$

$d = 327.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 19.13667$

$cc (5A.5, TBDY) = 0.00475778$

c = confinement factor = 1.27578

1 = $Asl_{ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.45459588$

2 = $Asl_{com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.45459588$

v = $Asl_{mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.99268896$

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

--->

$su (4.8) = 0.40159417$

$Mu = MRc (4.15) = 1.9001E+008$

u = $su (4.1) = 1.7086748E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.22053887$

$l_b = 300.00$

$l_d = 1360.304$

Calculation of $I_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 24.02082$$

$$K_{tr} = 0.82673491$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = 380.00$$

$$n = 20.00$$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.7086748E-005$$

$$\mu_u = 1.9001E+008$$

with full section properties:

$$b = 200.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.00165347$

Expression ((5.4d), TBDY) for psh_{min} has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 psh_x ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along Y) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 psh_y ((5.4d), TBDY) = $L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$

L_{stir} (Length of stirrups along X) = 960.00

A_{stir} (stirrups area) = 78.53982

A_{sec} (section area) = 120000.00

 $s = 380.00$

$f_{ywe} = 555.55$

$f_{ce} = 15.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00475778$

$c = \text{confinement factor} = 1.27578$

$y_1 = 0.0010562$

$sh_1 = 0.00365026$

$ft_1 = 304.185$

$fy_1 = 253.4875$

$su_1 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.22053887$

$su_1 = 0.4 * esu_{1,nominal}$ ((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, ASCE 41-17.

with $fs_1 = fs = 253.4875$

with $Es_1 = Es = 200000.00$

$y_2 = 0.0010562$

$sh_2 = 0.00365026$

$ft_2 = 304.185$

$fy_2 = 253.4875$

$su_2 = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.22053887$

$su_2 = 0.4 * esu_{2,nominal}$ ((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, ASCE 41-17.

with $fs_2 = fs = 253.4875$

with $Es_2 = Es = 200000.00$

$y_v = 0.0010562$

$sh_v = 0.00365026$

$ft_v = 304.185$

$fy_v = 253.4875$

$suv = 0.00365026$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/d = 0.22053887

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, ASCE 41-17.

with fsv = fs = 253.4875

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.29147618

2 = Asl,com/(b*d)*(fs2/fc) = 0.29147618

v = Asl,mid/(b*d)*(fsv/fc) = 0.6364888

and confined core properties:

b = 140.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 19.13667

cc (5A.5, TBDY) = 0.00475778

c = confinement factor = 1.27578

1 = Asl,ten/(b*d)*(fs1/fc) = 0.45459588

2 = Asl,com/(b*d)*(fs2/fc) = 0.45459588

v = Asl,mid/(b*d)*(fsv/fc) = 0.99268896

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) = 0.40159417

Mu = MRc (4.15) = 1.9001E+008

u = su (4.1) = 1.7086748E-005

Calculation of ratio lb/d

Lap Length: lb/d = 0.22053887

lb = 300.00

ld = 1360.304

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 555.55

fc' = 15.00, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

Ktr = 0.82673491

Atr = $\text{Min}(Atr_x, Atr_y)$ = 157.0796

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = 380.00

n = 20.00

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.7086748E-005

Mu = 1.9001E+008

with full section properties:

b = 200.00

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00442328$$

$$N = 4737.328$$

$$f_c = 15.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.018$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.018$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.15303423$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 51733.333$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$f_y = 0.15303423$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.43111111$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 0.00$$

$$b_{max} = 400.00$$

$$h_{max} = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.01016$$

$$b_w = 200.00$$

$$\text{effective stress from (A.35), } f_{fe} = 524.0792$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} = \text{Max}(((A_{conf,max} - A_{noConf}) / A_{conf,max}) * (A_{conf,min} / A_{conf,max}), 0) = 0.00$$

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.

$A_{conf,max} = 75600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the perimeter hoops.

$A_{conf,min} = 0.00$ 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.

$A_{noConf} = 33066.667$ is the unconfined core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.00165347$$

Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} \text{ (Length of stirrups along Y)} = 960.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 120000.00$$

$$p_{sh,y} \text{ ((5.4d), TBDY)} = L_{stir} * A_{stir} / (A_{sec} * s) = 0.00165347$$

$$L_{stir} \text{ (Length of stirrups along X)} = 960.00$$

$$A_{stir} \text{ (stirrups area)} = 78.53982$$

$$A_{sec} \text{ (section area)} = 120000.00$$

$$s = 380.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 15.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00475778$$

$c = \text{confinement factor} = 1.27578$
 $y1 = 0.0010562$
 $sh1 = 0.00365026$
 $ft1 = 304.185$
 $fy1 = 253.4875$
 $su1 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.22053887$
 $su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 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, ASCE 41-17.
 with $fs1 = fs = 253.4875$
 with $Es1 = Es = 200000.00$
 $y2 = 0.0010562$
 $sh2 = 0.00365026$
 $ft2 = 304.185$
 $fy2 = 253.4875$
 $su2 = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/lb,min = 0.22053887$
 $su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 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, ASCE 41-17.
 with $fs2 = fs = 253.4875$
 with $Es2 = Es = 200000.00$
 $yv = 0.0010562$
 $shv = 0.00365026$
 $ftv = 304.185$
 $fyv = 253.4875$
 $suv = 0.00365026$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.22053887$
 $suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 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, ASCE 41-17.
 with $fsv = fs = 253.4875$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.29147618$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.29147618$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.6364888$
 and confined core properties:
 $b = 140.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 19.13667$
 $cc (5A.5, \text{TBDY}) = 0.00475778$
 $c = \text{confinement factor} = 1.27578$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.45459588$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.45459588$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.99268896$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < vs, y2$ - LHS eq.(4.5) is not satisfied

--->
v < v_{s,c} - RHS eq.(4.5) is satisfied

--->
s_u (4.8) = 0.40159417
M_u = MR_c (4.15) = 1.9001E+008
u = s_u (4.1) = 1.7086748E-005

Calculation of ratio l_b/l_d

Lap Length: l_b/l_d = 0.22053887

l_b = 300.00

l_d = 1360.304

Calculation of l_{b,min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: f_y = 555.55

f_c' = 15.00, but f_c'^{0.5} <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 24.02082

K_{tr} = 0.82673491

A_{tr} = Min(A_{tr_x}, A_{tr_y}) = 157.0796

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = 380.00

n = 20.00

Calculation of Shear Strength V_r = Min(V_{r1}, V_{r2}) = 227350.021

Calculation of Shear Strength at edge 1, V_{r1} = 227350.021

V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl}*V_{Col0}

V_{Col0} = 227350.021

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' = 15.00, but f_c'^{0.5} <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/V_d = 2.00

M_u = 0.00988804

V_u = 1.5456333E-009

d = 0.8*h = 320.00

N_u = 4737.328

A_g = 80000.00

From (11.5.4.8), ACI 318-14: V_s = V_{s1} + V_{s2} = 0.00

where:

V_{s1} = 0.00 is calculated for section web, with:

d = 160.00

A_v = 157079.633

f_y = 444.44

s = 380.00

V_{s1} is multiplied by Col1 = 0.00

s/d = 2.375

V_{s2} = 0.00 is calculated for section flange, with:

d = 320.00

A_v = 157079.633

f_y = 444.44

s = 380.00

V_{s2} is multiplied by Col2 = 0.00

s/d = 1.1875

V_f ((11-3)-(11.4), ACI 440) = 188111.148

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) = 357.00

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: $V_s + V_f \leq 164661.611$

$bw = 200.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 227350.021$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{Col0}$

$V_{Col0} = 227350.021$

$k_n l = 1$ (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)

$f_c' = 15.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.00525978$

$V_u = 1.5456333E-009$

$d = 0.8 \cdot h = 320.00$

$N_u = 4737.328$

$A_g = 80000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 0.00$

where:

$V_{s1} = 0.00$ is calculated for section web, with:

$d = 160.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s1} is multiplied by $\phi_{Col1} = 0.00$

$s/d = 2.375$

$V_{s2} = 0.00$ is calculated for section flange, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 444.44$

$s = 380.00$

V_{s2} is multiplied by $\phi_{Col2} = 0.00$

$s/d = 1.1875$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, 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) = 357.00

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: $V_s + V_f \leq 164661.611$

$bw = 200.00$

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, $\gamma = 0.90$
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
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, $f_c = f_{cm} = 15.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 18203.022$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 400.00$
Min Height, $H_{min} = 200.00$
Max Width, $W_{max} = 400.00$
Min Width, $W_{min} = 200.00$
Eccentricity, $E_{cc} = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 1473.353$
Shear Force, $V_2 = 3961.043$
Shear Force, $V_3 = -0.77690092$
Axial Force, $F = -4742.638$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl} = 0.00$
-Compression: $A_{sc} = 5152.212$
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, $DbL = 17.60$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.0396757$

$$u = y + p = 0.04408411$$

- Calculation of y -

$$y = (M_y * L_s / 3) / E_{\text{eff}} = 0.00208411 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 1.3657E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 300.00$$

$$\text{From table 10.5, ASCE 41-17: } E_{\text{eff}} = \text{factor} * E_c * I_g = 6.5531E+012$$

$$\text{factor} = 0.30$$

$$A_g = 120000.00$$

$$f_c' = 15.00$$

$$N = 4742.638$$

$$E_c * I_g = 2.1844E+013$$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$$

$$y_{\text{ten}} = 5.8874430E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 235.317$$

$$d = 357.00$$

$$y = 0.44020587$$

$$A = 0.0724421$$

$$B = 0.04070795$$

$$\text{with } p_t = 0.0075814$$

$$p_c = 0.01724796$$

$$p_v = 0.03766391$$

$$N = 4742.638$$

$$b = 200.00$$

$$" = 0.12044818$$

$$y_{\text{comp}} = 1.0162879E-005$$

$$\text{with } f_c' \text{ (12.3, (ACI 440))} = 16.12972$$

$$f_c = 15.00$$

$$f_l = 0.93147527$$

$$b = b_{\text{max}} = 400.00$$

$$h = h_{\text{max}} = 400.00$$

$$A_g = 120000.00$$

$$g = p_t + p_c + p_v = 0.07215983$$

$$r_c = 40.00$$

$$A_e / A_c = 0.38686758$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$\text{effective strain from (12.5) and (12.12), } \epsilon_{\text{fe}} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 18203.022$$

$$y = 0.43961339$$

$$A = 0.0719516$$

$$B = 0.04042568$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio I_b / I_d

$$\text{Lap Length: } I_d / I_d, \text{min} = 0.27567359$$

$$I_b = 300.00$$

$$I_d = 1088.244$$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 444.44$$

$$f_c' = 15.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

s = 0.80
e = 1.00
cb = 24.02082
Ktr = 0.82673491
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis
s = 380.00
n = 20.00

- Calculation of ρ -

From table 10-8: $\rho = 0.042$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$

shear control ratio $V_y E / V_{col} E = 0.55718248$

d = 357.00

s = 0.00

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = A_v * L_{stir} / (A_g * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.0075814$

$A_v = 78.53982$, is the area of every stirrup

$L_{stir} = 960.00$, 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 = 4742.638

$A_g = 120000.00$

$f_{cE} = 15.00$

$f_{tE} = f_{yE} = 444.44$

$\rho_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.07215983$

b = 200.00

d = 357.00

$f_{cE} = 15.00$

End Of Calculation of Chord Rotation Capacity for element: column TC1 of floor 1

At local axis: 3

Integration Section: (b)